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Structure of the USDA Livestock and Poultry Baseline Model

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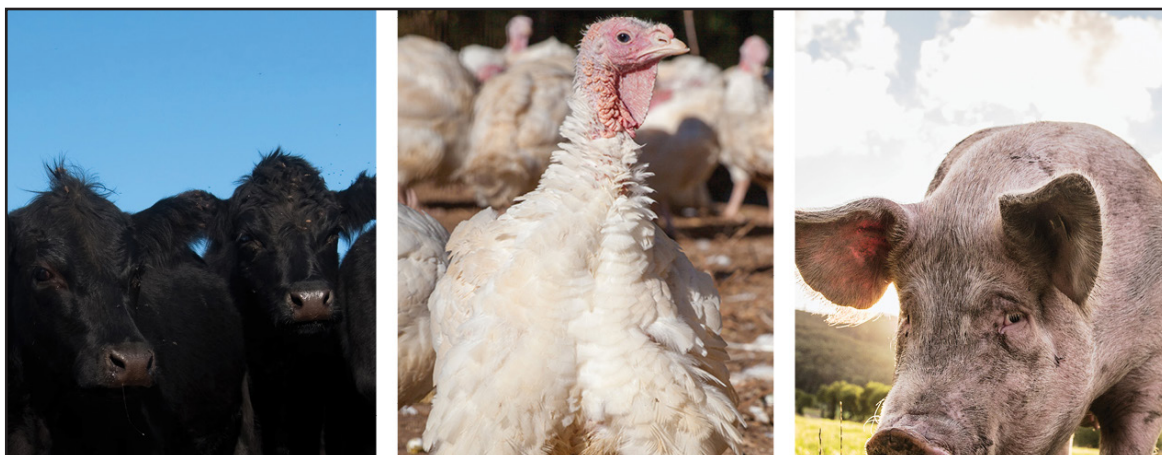
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Structure of the USDA Livestock and Poultry Baseline Model

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Abstract

The U.S. Department of Agriculture (USDA) produces annual 10-year projections for the food and agriculture sector that cover major agricultural commodities, agricultural trade, and aggregated indicators of the U.S. farm sector. These projections are published in an annual report, with the most recent being *USDA Agricultural Projections to 2031*. Also, the *Economic Report of the President* includes these projections and has a direct impact on policy decisions. These 10-year projections are called the "baseline."

The USDA's Economic Research Service (ERS) maintains a stand-alone livestock baseline model, which characterizes the relationships among livestock production and the market conditions for related animal products for cattle/beef, hogs/pork, chicken, and turkey. This bulletin outlines the equations used to create the livestock baseline. These equations were used in the creation of the 2031 baseline report.

Keywords: Beef, cattle, hogs, pork, broilers, turkey, supply, demand, economic modeling, simultaneous equation systems, U.S. Agricultural Baseline Projections, USDA, ERS, Economic Research Service, U.S. Department of Agriculture

Acknowledgments

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What Is the Issue?

The U.S. Department of Agriculture (USDA) produces annual 10-year projections for the food and agriculture sector that cover major agricultural commodities, agricultural trade, and aggregated indicators of the U.S. farm sector. These projections are published in an annual report, with the most recent being *USDA Agricultural Projections to 2031*. Also, the *Economic Report of the President* includes these projections and has a direct impact on policy decisions. These 10-year projections are called the "baseline."

The USDA's Economic Research Service (ERS) maintains a stand-alone livestock baseline model used in the development of the projections, which characterizes the relationships among livestock production and the market conditions for related animal products for cattle/beef, hogs/pork, chicken, and turkey. The livestock baseline model combines data, parameters, and equations from different sources into a single model. This bulletin outlines the equations and estimates of the Domestic Baseline Livestock Model (DBLM), a dynamic, nonlinear simultaneous equation model of the U.S. domestic supply, demand, and pricing systems for the beef, pork, broilers, and turkey sectors. These estimates and equations were used to create the 2021 baseline projections and differ from those used in previous baseline projections. Some of the equations in the newest model are similar to those used in the previous model but with different coefficients. Other equations use different structures and data. The goal was to build a model that would project the production, consumption, and prices of the cattle/beef, hog/pork, broiler, and turkey sectors. Most of the variables the model projects are also reported in the livestock and poultry sections of the *World Agricultural Supply and Demand Estimates* (*WASDE*) report.
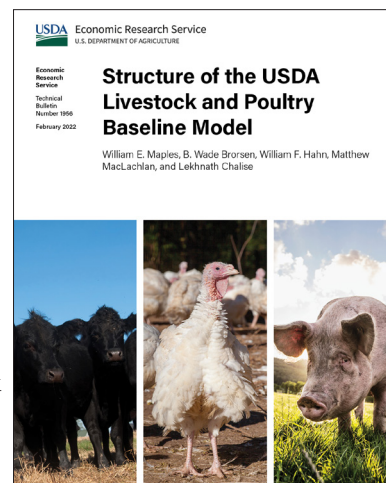
What Did the Study Find?

Most of the equation-parameter estimates of the livestock baseline model are consistent with prior studies and economic expectations. The supply-side equations imply that higher prices for an animal or its meat and/or lower costs of production lead to larger supplies of an animal and its products. On the demand side, higher retail prices for a particular meat lead to lower consumer demand for that meat. Also, higher retail prices for a meat are associated with its higher wholesale and livestock prices. The new specifications and estimates were incorporated into the development of the 2021 livestock baseline and will inform future projections.

How Was the Study Conducted?

The researchers reviewed previous literature and consulted with USDA personnel responsible for the livestock baseline and models to develop equations used in this bulletin. Based on these equations, regression models were developed using published Government data. A full list of resources is available in the appendix.

Structure of the USDA Livestock and Poultry Baseline Model

Introduction

The U.S. Department of Agriculture (USDA) produces annual 10-year projections for the food and agriculture sector that cover major agricultural commodities, agricultural trade, and aggregate indicators of the U.S. farm sector. These projections are published in an annual report. The most recent was *USDA Agricultural Projections to 2031* (U.S. Department of Agriculture, 2022). The *Economic Report of the President* also includes these projections, which has a direct impact on policy decisions. These 10-year projections are called the "baseline." To develop the projections, the USDA relies on expert opinion and a variety of economic models called "baseline models." These equations represent the supply and demand for sets of agricultural commodities. The U.S. Department of Agriculture, Economic Research Service (ERS) maintains the baseline models. The domestic baseline includes partial equilibrium models for corn, soybeans, wheat, barley, sorghum, oats, cotton, rice, fruit and vegetables, sugar, and dairy; a farm income module; more than 40 country modules; and a Domestic Baseline Livestock Model (DBLM). The equations in this bulletin were used in the DBLM to produce the 2021 Baseline.

This bulletin outlines the source data used to generate forecasts, the equations used in this model, and the estimated coefficients. The DBLM consists of production, demand, and price transmission sections for the U.S. cattle/beef, hogs/pork, broilers/chicken, and turkey sectors. The DBLM can be evaluated and estimated as a stand-alone model.[1] The DBLM and other U.S. commodities and foreign country models are linked and solved simultaneously using a process outlined by Hjort et al., (2018).

This bulletin focuses on the DBLM and not on the livestock baseline process. The DBLM has equations that project production and prices for livestock, poultry, and meat based on predicted trade, input costs, and macroeconomic conditions. Many of these equations have coefficients that are estimated using statistical techniques. This bulletin outlines the equations and their estimates. The equations in the DBLM estimate historical relationships among important variables driving livestock, poultry, and meat markets.

In practice, the equations in the DBLM only account for some factors driving livestock, poultry, and meat markets. During the baseline process, analysts use their judgment to account for factors not included in the DBLM equations. The DBLM is incorporated in solver software that creates a livestock baseline using a mixture of the DBLM equations and expert opinion. Boussios et al., (2021) noted short-term forecasts that use a mix of modeling and analyst judgment may be more accurate than forecasts using modeling only. Conversely, trends in the data perform better for long-term projections. To incorporate these insights, the DBLM includes trends. While linkages among the various domestic and international models, as well as the mixing of expert opinion and historical patterns are important to create the domestic livestock baseline, these baseline-creation processes are not needed in the DBLM's estimation.

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[1]In the baseline process, the DBLM incorporates and uses data generated by other baseline models and serves as a source of data for other baseline models. For example, corn is an important factor in livestock and poultry production. Meat production shifts the demand for corn and other feedstuffs. DBLM needs feed-cost projections from the grain and oil-seeds models, trade projections from other baseline models, and macroeconomic forecasts.

Overview of the Model and Its Equations

Three sets of equations comprise Domestic Baseline Livestock Model, (DBLM): demand, production, and price transmission. The production equations are grouped by species: cattle/beef, hogs/pork, broilers/chicken, and turkey. Most of the production equations in the DBLM are based on Weimar and Stillman (1990), which is based on the quarterly livestock model of Stillman (1985). The DBLM differs substantively from Weimer and Stillman in its data usage and specification of the demand and price-transmission equations.

The DBLM is a dynamic, non-linear simultaneous equation model. "Simultaneous" means that current prices drive production and demand. To forecast or obtain a projection from the DBLM, forecasted prices, production levels, and demand must be estimated. All equations need to be mutually consistent. Some equations are non-linear; for example, the DBLM calculates the total domestic supply of pork by multiplying hogs slaughtered, determined in one equation, by the average weight of hogs, determined in another equation. The demand equations use logarithms of prices and quantities. The nonlinear features of the DBLM make it more challenging for the software to solve it.

Economists use the term "dynamic" to refer to equations where current values are affected by values from previous periods. Livestock production is characterized by relatively long time lags from when the decision is made to produce until a marketable product is sold. Most of the cattle slaughtered in 1 year were born in previous years. So, for example, if more calves are born this year than usual, more cattle will be available for slaughter in following years.

Three types of equations are in this bulletin. The first type has unknown parameters and must be estimated using econometric methods. These equations are numbered from 1 to 36. The four retail meat demand equations have a similar mathematical form; these equations can be written using a generic equation. The bulletin shows two alternative versions for the demand equations.

The second type of equation is an identity equation, which is true by definition. For example, the DBLM has equations to explain five types of cattle slaughter: steer, heifer, bull, beef cow, and dairy cow. Total cattle slaughter is the sum of the five types. The total cattle slaughter equation is an identity. Fifteen identities are in the DBLM. With 38 estimated equations and 15 identities, the DBLM explains 53 livestock, poultry, and meat variables. The variables explained by the model and their sources are listed in appendix A. The identity equations are denoted using two letters and a number.

The third type of equation represents costs and returns formulas. USDA livestock analysts use feed formulas to calculate the costs of feeding different animals. The DBLM uses these feed costs in the production equations. The DBLM also uses simplified costs and returns formulas from the previous model. These costs and return formulas are denoted using three letters.

This bulletin documents the DBLM. The coefficient estimates are used in the development of the livestock baseline, whereas standard errors and model fits are not. However, model fits are used to evaluate the in-sample performance of the DBLM. The DBLM includes many cases where one equation uses variables from other equations. The true measure of a simultaneous equation system's fit is how well it predicts a variable given the predicted variables from other equations. Appendix B has graphs of the endogenous variables in the DBLM and their predicted values when all the equations are solved simultaneously. Appendix C illustrates the use of the DBLM for scenario analysis.

Data in the DBLM

The Domestic Baseline Livestock Model (DBLM) projects prices and quantities of livestock, poultry, and meat. Many prices in the DBLM are those forecast in USDA's *World Agricultural Supply and Demand Estimates* (*WASDE*) and USDA *Livestock, Dairy, and Poultry Outlook* (LDP) reports. The *WASDE* and LDP reports project no more than 2 years ahead; baseline projections cover 10 years. Appendix A provides a complete list and discussion of the data sources used in the DBLM.

The DBLM equations are estimated using annual data. The last year used to estimate the equations was 2018. Most of the data starts in 1990 (1990 to 2018 is 28 years of data). The price data start in 1989, marking the beginning of 39 years of data. Some of the supply and demand equations can be estimated using 38 observations. As noted above, some of the equations depend on data from the previous years. This can limit the number of observations used to estimate an equation. For example, the beef cow inventory equation, equation 3 below, depends on last year's beef cow inventory. The database does not have 1989 beef cow inventory numbers in it. Equation 3 is estimated using 1990 inventories to explain 1991 inventories, 1991 inventories to explain 1992, and so on.

Four demand equations are in the DBLM: one each for beef, pork, broilers, and turkey. Each equation relates the per-capita disappearance of beef, pork, broilers, and turkey to the retail prices for these meats and per-capita disposable income (PCDI). Economists use the term "elasticity" to discuss how quantities demanded (or supplied) respond to changes in prices or other factors. The demand equations enable calculating the elasticities of demand for all four types of meat while accounting for prices and income. The demand equations in the DBLM are linear in logarithms, or log-linear. One advantage of log-linear functions is that the coefficients of the equations are elasticities.

Demand Equations

A log-linear demand equation is written:

$$(1) \qquad \ln q_{i,t} = \sum_j \varepsilon_{i,j} \ln p_{j,t} + \eta_i \ln x_t + a_i + b_i t + u_{i,t}$$

where:

$\quad$ ln indicates the natural logarithm function

$\quad$ $q_{i,t}$ is the per capita demand for meat ( ) in the year numbered t, where $i =$ {Beef, Pork, Chicken, or Turkey}

$\quad$ $p_{j,t}$ is the retail price of product j; j is one of the four meats

$\quad$ x_t is per-capita disposable personal income, and

$\quad$ $u_{i,t}$ is a random error term.

All four prices and disposable personal income are corrected for inflation by deflating them by the overall Consumer Price Index (CPI).

The terms $\varepsilon_{i,j}$ are the price elasticities and η_i the income elasticities. The terms a_i and b_i are intercepts and trend coefficients. The b_i times t allows for trends in consumption. A positive value for b_i makes the quantity demanded of meat (i) grow over time, unless offset by changes in prices or expenditures. The elasticities, intercepts, and trend coefficients are unknown and estimated.

The set of equations is estimated simultaneously, using a version of generalized methods of moments (GMM). GMM is often used to estimate equations or sets of equations when some explanatory variables are simultaneously determined with the endogenous variables. The interaction between the meat demand and meat supply equations makes the quantities of meat purchased and their prices simultaneously determined.

The error terms in all four equations had autoregression. An equation with autoregression can be written:

$$(2) \qquad \ln q_{i,t} - \rho_i \ln q_{i,t-1} = \sum_j \varepsilon_{i,j}(\ln p_{j,t} - \rho_i \ln p_{j,t-1}) + \eta_i(\ln x_t - \rho_i \ln x_{t-1}) + a_i + b_i t + u_{i,t}$$

In equation 2, ρ_i is an estimated first-order autoregression term. Note the previous year's quantities, prices, and expenditures are multiplied by the autoregression term and subtracted from the current values. This treatment was not applied to the intercepts and trends. Statistically insignificant elasticities were eliminated from the equations and fixed to 0. Elasticities and other parameter estimates for equation 2 are shown in table 1.

Table 1
Demand parameter estimates (based on equation 2)

Quantity demanded	Elasticities of demand with respect to prices and income					Other coefficient estimates		
	Beef	**Pork**	**Chicken**	**Turkey**	**Income**	**Intercept**	**Trend**	**Auto-regression**
Beef	–0.559				0.590	0.548	–0.003	0.709
Pork	0.199	–0.790			0.410	0.462	–0.001	0.853
Chicken	0.123		–0.584		0.374	0.625	0.001	0.757
Turkey	0.096		0.258	–0.885	–1.988	19.746	0.016	0.172

Note: Blank cells in the table had statistically insignificant estimates and are set to 0.

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; U.S. Department of Labor, Bureau of Labor Statistics; and U.S. Department of Commerce, Bureau of Economic Analysis.

All of the own-price elasticities are negative and relatively inelastic: all range between 0 and 1. Own-price elasticities for meat and other foods are generally relatively inelastic. Most of the cross-price elasticities were statistically insignificant and set to 0. The beef equation has no significant cross-price elasticities. Beef prices, however, affect demand for the other three meats. Chicken prices affect turkey demand. All the non-zero cross-price elasticities are positive. The positive cross-price elasticities for beef prices imply that as beef prices increase, demand for pork, chicken, and turkey increase. Economists generally interpret positive cross-price elasticities to mean the goods are substitutes for one another.

Beef, pork, and chicken demands increase as income increases, whereas turkey demand declines. Products whose demand declines as income increases are called "inferior goods." Beef and pork have negative trend terms; if prices and income were fixed over the years, the demand estimates imply that the demands for these meats would decline. The coefficient of 0.003 for beef implies a three-tenths of a percent decline in beef demand year to year. Turkey and chicken both have increasing trends in demand.

Over the sample period, the growth in income and the positive income elasticities were strong enough to offset the negative trend effects for beef and pork. So, their demand would tend to expand if their real prices were fixed. Chicken demand has a positive trend and is positively affected by income growth. The net effect of the trend and income effects on turkey demand were generally negative over the sample period.

Data in the Demand Equations

The per-capita quantities in the demand equations are the annual per-capita disappearance reported in the *WASDE* and LDP reports. The beef price is the ERS Choice beef retail value. The pork price is the ERS retail value. These retail composites measure the costs of buying an entire animal's meat at the grocery store. ERS calculates beef and pork composites using beef- and pork-cut prices reported by the Bureau of Labor Statistics (BLS). The retail chicken and turkey prices in the demand system are BLS prices for whole broilers and turkeys. These annual prices are simple averages of monthly prices as reported by ERS or BLS. The income and population estimates come from the U.S. Department of Commerce, Bureau of Economic Analysis (BEA).

The Supply Equations

Most of the supply equations in the Domestic Baseline Livestock Model (DBLM) are based on equations first developed by Stillman (1985) and modified by Weimar and Stillman (1990). ERS used these supply equations for over 20 years; see Kingsbury et al., (2002) for a historical perspective on the livestock baseline model. (The 1985 and 1990 equations are called the Stillman-Weimar equations in this report.) In developing the current DBLM, ERS and other USDA personnel involved with the baseline process were interested in maintaining the supply-side features of the previous model if it were practical and effective to do so.[2]

Some of the Stillman-Weimar equations included calculated net returns to various livestock or poultry enterprises. The Stillman-Weimer net return formulas were used in the DBLM. The net-return formulas used current sales prices to index a base return and current input costs as an index for base costs. For example, for cow/calf producers, the output price index was a mix of feeder calf and cull/cow prices. If that index increased by 5 percent between 1985 and 1986, revenues increased by the same percentage. Various cost items were indexed in a similar manner. These net return formulas can be a function of output and input costs directly, rather than sequentially multiplying percent changes. This simplifies the net return formulas, makes them more understandable, and simplifies calculations when solving the DBLM.

The Beef/Cattle Sector

Of the four animal species included in the Domestic Baseline Livestock Model, cattle production and processing requires the most time. Cattle may also be placed in a variety of paths between birth and the packing plant. Gestation in cattle is around 285 days, and most calves are born in the spring. Calves are about 65 pounds at birth and kept with their mothers until they reach a weaning weight of about 550 pounds. Time required from birth to weaning can take from 90 to 205 days. Generally, the longer the time a calf spends with its mother, the higher its weaning weight. Upon weaning, an animal can be sent to various routes before arriving at a feedlot. The route from weaning to slaughter depends on various economic and environmental factors.

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[2] A major focus of this technical bulletin is on improving the demand equations. The changes in the demand-equation structure and the data used in the demand equations required changes in the price-transmission equations.

Pre-conditioning is a short stage some cow/calf producers use to transition animals to dry feed. In this phase, calves are introduced to the types of feed they will eat at the feedlot. Cow/calf production is largely done on pastures or ranges with little feeding of grain. Pre-conditioning is beneficial for the animal's health and lasts about 35 days until the animal is sent to a feedlot. Once at the feedlot, the animal reaches slaughter weight in about 230 days. Pre-conditioned cattle might also be sent to graze on summer or winter grass before being sent to the feedlot.

Backgrounding is a stage where weaned animals are fed dry forage, silage, and grain until about 800 pounds and then sent to the feedlot. Backgrounding can last about 100 days. Once at the feedlot, it takes about another 160 days for the animal to reach slaughter weight. A final route for weaned animals on the way to the feedlot is the stocker stage, where they are fed dry forage over the winter and then graze on summer grasses before being sent to the feedlot. This stage can last almost a year. These animals will then spend about 100 days in the feedlot until they reach slaughter weight.

Data

Data for the cattle and beef sector consist of two types. The first is inventory data. All cattle inventory data come from the January 1 U.S. Department of Agriculture National Agricultural Statistics Service (NASS) *Cattle* report. (Appendix A provides details about this and other data cited in this bulletin.) Inventory data shows how many animals of each type were on hand January 1 of each year. The Domestic Baseline Livestock Model contains equations to explain beef cow inventory, steers larger than 500 pounds, other heifers larger than 500 pounds, heifers larger than 500 pounds kept for beef cow replacement, bulls larger than 500 pounds, and calves smaller than 500 pounds. The DBLM also uses the dairy cow inventory from the NASS January 1 *Cattle* report in its equations. ERS uses a dairy baseline model to determine the dairy cow inventory numbers.

The second type of data are flows. Flow data show total production for a year. Variables included are calf crop, steer slaughter, heifer slaughter, bull slaughter, cow slaughter, and cattle slaughter weights.

Equations for the Beef/Cattle Sector

Beef cow inventory reflects the number of beef cows on January 1 and provides a measure of the present and future production capacity of the cattle and beef sector. Equation 3 explains the January 1 beef cow inventory.

(3) $Beef\ Cow\ Inventory_t = ca10 + ca11 * Beef\ Cow\ Inventory_{t-1} + ca12 * Beef\ Replacement\ Heifers_{t-1}$
        $+ ca13 * Beef\ Cow\ Slaughter_{t-1} + \mu_t$

Equation 3 is a function of the beef cattle inventory in the previous year: number of replacement heifers and number of beef cows slaughtered.

In this section, coefficients of the supply equations are written as *ca??* where the letters *ca* are cattle coefficients and the *??* stands for a 2- or 3-digit number. Coefficients that end with 0 are intercepts, such as *ca10* in equation 3. The term μ_t is a random error term for an equation. The same symbol is used for all equation errors, though all these errors are different. Coefficient estimates for equation 3 are in table 2.

Table 2
Beef cow inventory – January 1, 1,000 head

Variable	Coefficient
Intercept	–799.616
Lag (Beef cow inventory)	0.965
Lag (Heifers kept for replacement)	0.725
Lag (Beef cow slaughter)	–0.738

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Equation 3 indicates that current beef cow inventory is positively associated with last year's beef cow inventory and last year's heifers kept for replacement. Last year's cow slaughter decreases this year's beef cow inventory.

Calf Crop is the total number of calves born each year and includes both beef and dairy calves. Calf Crop in year t is a function of the total cow inventory on January 1 of year t. The equation is:

(4) $Calf\ Crop_t = ca21 * (Beef\ Cow\ Inventory_t + Dairy\ Cow\ Inventory_t) + \mu_t$

The coefficient estimate for equation 4 is in table 3.

Table 3
Calf crop – January 1, 1,000 head

Variable	Coefficient
Beef cow inventory + Dairy cow inventory	0.891

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Estimates for equation 4 imply that 89.1 percent of the cows on hand January 1 give birth in the average year.

The number of steers larger than 500 pounds (*Steers*) is measured as January 1 inventory. It is a function of *Net Calf Crop*. The definition of *Net Calf Crop* is:

$Net\ Calf\ Crop_t = Calf\ Crop_t - Calf\ Slaughter_t + Cattle\ Imports_t - Cattle\ Exports_t$

Where each is measured in 1,000 head. Other equations in the DBLM also use *Net Calf Crop* as an independent variable. *Cattle Imports, Cattle Exports,* and *Calf Slaughter* are treated as exogenous to the DBLM.

The steers-larger-than-500-pounds equation is:

(5) $Steers_t = ca30 + ca31 * Net\ Calf\ Crop_{t-1} + \mu_t$

Coefficient estimates for equation 5 are in table 4.

Table 4
Steers larger than 500 pounds, 1,000 head

Variable	Coefficient
Intercept	5,818.009
Lag (Net calf crop)	0.284

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

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USDA, Economic Research Service

Estimates indicate the total steers larger than 500 pounds is positively related to the previous year's *Net Calf Crop*.

The number of other heifers larger than 500 pounds not kept for dairy or beef cow replacement (*Other Heifers*) is measured as a January 1 inventory. It is a function of *Net Calf Crop* and *Real Cow-Calf* producer net returns. The other heifer equation is:

(6) $Other\ Heifers_t = ca50 + ca51 * Net\ Calf\ Crop_t + ca52 * Real\ Cow - Calf\ Returns_{t-1} + \mu_t$

Coefficient estimates for equation 6 are in table 5.

Table 5
Other heifers larger than 500 pounds, 1,000 head

Variable	Coefficient
Intercept	4,378.195
Lag (Net calf crop)	0.131
Lag (Real cow-calf returns)	−4.409

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Real Cow-Calf Returns are formulas driven by a cull-cow price (*CCP*); feeder calf price (*FCP*); the Producer Price Index for all commodities[3] (*PPI*); the corn price (*Corn*); the soybean oil meal price, (*SBOM*); the hay price (*Hay*); and a farm wage rate reported by USDA, National Agricultural Statistics Service (NASS). Corn, SBOM, and hay prices were taken from *WASDE* reports. Corn, hay, and SBOM prices used in equation 6 are used elsewhere in the DBLM. The net return before correcting for inflation is:

(CCR) $Cow - Calf\ Returns_t = 0.436 * CCP_t + 3.023 * FCP_t - 1.415 * PPI_t$
$- 1.992 * Wage_t - 5.975 * Corn_t - 0.103 * SBOM_t - 0.861 * Hay_t$

Both cattle prices are measured in dollars per hundredweight (cwt); wages are in dollars per hour; the corn price is dollars per bushel; and both *SBOM* and hay prices are dollars per ton. The two cattle prices are determined within the DBLM; the cost variables are exogenous to the DBLM. Cow/calf returns are divided by the CPI to convert them to real returns. The CPI is normalized so that it averages 100 between 1982 and 1984. The CPI for 2020 was 259. A $1 change in the real price of an item translates to $2.59 in its 2020 nominal price.

The number of heifers larger than 500 pounds kept for beef cow replacements (*Beef Replacement Heifers*) is measured as a January 1 inventory. Replacement heifers are kept to replenish or expand the cowherd. *Beef Replacement Heifers* is a function of the previous year's *Beef Cow Inventory* and lagged cow-calf producer returns. The beef replacement heifer equation is:

(7) $Beef\ Replacement\ Heifers_t = ca60 + ca61 * Beef\ Cow\ Inventory_{t-1}$
$+ ca62 * Real\ Cow\ Calf\ Returns_{t-1} + ca63 * Real\ Cow\ Calf\ Returns_{t-2} + \mu_t$

Coefficient estimates for equation 7 are in table 6.

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[3]BLS also calculates the PPI. In this case, "commodities" are all inputs to production and "producers" are all manufacturing firms.

Table 6
Heifers larger than 500 pounds kept for beef cow replacements, 1,000 head

Variable	Coefficient
Intercept	3,245.094
Lag (Beef cow inventory)	0.082
Lag (Real cow-calf returns)	2.096
Lag 2 (Real cow-calf returns)	1.887

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Note that the once- and twice-lagged real net returns coefficients are positive. Higher real net returns this year usually result in higher heifers retained in the next 2 years. Net returns increase when cattle prices increase and decrease when input costs increase.

The number of bulls larger than 500 pounds (*Bulls)* is measured as a January 1 inventory. The *Bulls* equation is a function of an intercept, trend, and last year's bull inventory.[4]

(8) $Bulls_t = ca71 + ca71 * t + ca72 * Bulls_{t-1} + \mu_t$

The term t in equation 8 is a time trend. For the purposes of the DBLM, the t for 1990 is 1, 1991 is 2, and so on. Coefficient estimates for equation 8 are in table 7.

Table 7
Bulls larger than 500 pounds, 1,000 head

Variable	Coefficient
Intercept	518.690
Trend	–1.479
Lag (Bulls)	0.779

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

The number of calves smaller than 500 pounds (*Calves)* is measured as a January 1 inventory. It is a function of the *Net Calf Crop*. The equation is:

(9) $Calves_t = ca80 + ca81 * Net\ Calf\ Crop_{t-1} + \mu_t$

Coefficient estimates for equation 9 are in table 8.

Table 8
Calves smaller than 500 pounds, 1,000 head

Variable	Coefficient
Intercept	–10,998.100
Lag (Net calf crop)	0.704

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Steer Slaughter is the total number of steers slaughtered in federally inspected (FI) facilities. It is a function of the numbers of steers larger than 500 pounds (*Steers)* and calves less than 500 pounds (*Calves)* on January 1 of the given year and the ratio of FI slaughter of all cattle to commercial slaughter of all cattle (*FI Ratio).*

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[4]This bull-inventory equation has a different form than that found in the Stillman-Weimar model.

(10) $Steer\ Slaughter_t = ca90 + ca91 * (Steers_t * FI\ Ratio_t) + ca92 * (Calves_t * FI\ Ratio_t) + \mu_t$

The *FI Ratio* is calculated by NASS and is the total number of cattle slaughtered FI plants divided by total commercial cattle slaughter:

$$FI\ Ratio_t = \frac{Federally - Inspected\ Cattle\ Slaughter_t}{Commercial\ Cattle\ Slaughter_t}$$

In the database used to estimate the DBLM, the *FI Ratio* varies slightly over time ranging between 97.4 and 98.6 percent; later years tend to have the highest ratios. Livestock analysts select an *FI Ratio* term for the projection years when building a livestock baseline. Coefficient estimates for equation 10 are in table 9.

Table 9
Federally inspected (FI) steer slaughter, 1,000 head

Variable	Coefficient
Intercept	1,410.283
Steers * FI ratio	0.833
Calves * FI ratio	0.113

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Note that the steers larger than 500 pounds coefficient is larger than the calves coefficient. Both are positive, but the beginning inventory of steers has a larger effect on a year's steer slaughter than the calves. The smaller coefficient for calves makes sense as these light calves are further from their market weight and some are heifers.

Heifer Slaughter is the total number of head of heifers slaughtered in federally inspected facilities. It is a function of the number of all heifers greater than 500 pounds, *Dairy Cow Inventory*, and *Real Cow Calf Returns*. The equation is:

(11) $Heifer\ Slaughter_t = ca100 + ca101 * (Other\ Heifers_t + Beef\ Replacement\ Heifers_t) * FI\ Ratio_t$
        $+ ca102 * Dairy\ Cow\ Inventory_t + ca104 * Real\ Cow\ Calf\ Returns_t$
        $+ ca105 * Real\ Cow\ Calf\ Returns_{t-1} + \mu_t$

Coefficient estimates for equation 11 are in table 10.

Table 10
Federally inspected (FI) heifer slaughter, 1,000 head

Variable	Coefficient
Intercept	−6,984.400
(Other heifers + heifers kept for replacement)*FI ratio	1.162
Dairy cow inventory	−0.097
Real cow-calf returns	−1.554
Lag (Real cow-calf returns)	−6.543

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The negative sign for current and lagged returns in equation 9 means fewer heifers are usually slaughtered when cow calf returns are higher.

Beef-Cow Slaughter is the total head of beef cows slaughtered in federally inspected facilities. It is a function of *Beef Cow Inventory* on January 1 of the given year and *Real Cow Calf Returns*.

(12) $Beef\ Cow\ Slaughter_t = ca120 + ca121 * Beef\ Cow\ Inventory_t * FI\ Ratio_t$
          $+ ca122 * Real\ Cow\ Calf\ Returns_{t-1} + \mu_t$

Coefficient estimates for equation 12 are in table 11.

Table 11
Federally inspected (FI) beef cow slaughter, 1,000 head

Variable	Coefficient
Intercept	−191.369
(Beef cow inventory)*FI ratio	0.099
Lag (Real cow calf returns)	−2.971

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The negative sign on the *Real Cow Calf Returns* coefficient implies that producers will keep more head of cows when they are more profitable. The beef cow inventory equation, equation 3, is a function of lagged cow slaughter. Higher returns lead to lower cow slaughter, which then increases next year's cow herd.

Dairy Cow Slaughter is the total head of dairy cows slaughtered in federally inspected facilities. It is a function of the current *Dairy Cow Inventory*:

(13) $Dairy\ Cow\ Slaughter_t = ca130 + ca131 * Dairy\ CattleInventory_t + \mu_t$

Coefficient estimates for equation 13 are in table 12.

Table 12
Federally inspected (FI) dairy cow slaughter, 1,000 head

Variable	Coefficient
Intercept	−4,418.300
Dairy cow inventory	0.776

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

The current dairy cow inventory is positively related with dairy cow slaughter.

Bull Slaughter is the total head of bulls slaughtered in federally inspected facilities. It is a function of the total head of cows on January 1 of the given year.

(14) $Bull\ Slaughter_t = ca140 + ca141 * (Beef\ Cow\ Inventory_t + Dairy\ Cow\ Inventory_t) + \mu_t$

Coefficient estimates for equation 14 are table 13.

Table 13
Federally inspected (FI) bull slaughter, 1,000 head

Variable	Coefficient
Intercept	−692.407
(Beef cow inventory + Dairy cow inventory)	0.031

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Bull Slaughter is positively related with the total of beef and dairy cow January 1 inventory.

Cattle Carcass Weight is a function of a time trend due to genetic and technology advancement and the real price of corn, which is a major component in feeding. It is also a function of the number of cattle slaughtered that year. When there are fewer cattle, prices tend to be higher, and cattle feeders may feed their cattle to higher weights.

(15) $Cattle\ Carcass\ Weight_t = ca150 + ca151 * Trend_t + ca152 * Real\ Corn\ Price_t$
$+ ca153 * Commercial\ Cattle\ Slaughter_t + \mu_t$

Coefficient estimates for equation 15 are in table 14.

Table 14
Cattle slaughter weight, pounds

Variable	Coefficient
Intercept	831.107
Time trend	4.890
Real corn price	−12.098
Commercial cattle slaughter	−0.004

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

When faced with higher corn prices, producers feed cattle to lighter weights. An increase of real corn prices by $1 per bushel decreases carcass weights by slightly over 12 pounds. At 2020 price levels, a $1 increase in corn translates to an increase of approximately $2.59 per bushel. The trend coefficient implies that cattle weights tend to increase by almost 5 pounds per year. A concern of some people in the industry is that slaughter weights are becoming too large (Maples et al., 2018; Bir et al., 2018). Since 2000, the slaughter weight increased by about 75 pounds. Maples et al., and Bir et al., believe this cattle-carcass-weight trend cannot continue.

The beef/cattle system in the DBLM needs some *identity equations*. *Identity equations* are true by definition and do not have to be estimated. The first identity equation is the *Commercial Cattle Slaughter* (CA1).

The FI Ratio is defined by FI slaughter divided by commercial slaughter. We can get FI slaughter by adding up the slaughter by class as follows:

Federally Inspected Cattle Slaughter_t = Steer Slaughter_t + Heifer Slaughter_t + Dairy Cow Slaughter_t + Beef Cow Slaughter_t + Bull Slaughter_t

(CA1) $\dfrac{Federally - Inspected\ Cattle\ Slaughter_t}{Commercial\ Cattle\ Slaughter_t} = FI\ Ratio_t$

All slaughter numbers in CA1 are measured in 1,000 head.

The next beef identity calculates total *Commercial Beef Production*, in pounds, from *Commercial Cattle Slaughter* and the average carcass weight of cattle:

(CA2)   *Commercial Beef Production$_t$ = (Commercial Cattle Slaughter$_t$) * (Cattle Carcass Weight$_t$)*

The DBLM has two more beef identities. One calculates total beef disappearance in pounds, a measure of beef consumption. *WASDE* reports contain supply and utilization tables for a wide variety of commodities. The totals on the supply side of the table equal the total on the utilization side.

(CA3)   *Beef Starting Stocks$_t$ + Beef Imports$_t$ + Commercial Beef Production$_t$ + Farm Beef Production$_t$*
        = Beef Starting Stocks$_{t+1}$ + Beef Exports$_t$ + Beef Disappearance$_t$

CA3 has another built-in identity; the stocks at the end of year *t* are the stocks at the start year *t+1*. *Farm Beef Production*, beef trade, and beef stocks are exogenous to the DBLM.[5] *Per-Capita Beef Disappearance*, used in the beef demand equation, is total *Beef Disappearance* divided by the U.S. population:

(CA4)   *Per-Capita Beef Disappearance$_t$ = Beef Disappearance$_t$ / Population$_t$*

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[5]Trade, stocks, and farm slaughter are exogenous to the DBLM for all four species.

The Pork/Hogs Sector

In comparison with beef, pork production has a much shorter timeframe. It takes about 6 months to raise a hog from birth to slaughter. Gestation in sows takes 114 days. With this short gestation period, sows will have two–three litters in a year. This is the production process for the vast majority of hogs in the United States: When a sow is ready to give birth (farrow), she is moved to a farrowing barn to give birth to piglets. In 2017, the average number of pigs per litter was 10.49 compared to 8.81 in 2000. Sows nurse the piglets until weaning at 21 days of age. At weaning, piglets are moved to a nursey where they grow to 50 to 60 pounds. The pigs are then moved to a finishing barn where they spend 16 to 17 weeks and reach market weight. In recent years, the average market weight of hogs ranged between 275 and almost 300 pounds.

Equations

Like the cattle equations, the hog equations have both stock and flow variables. The stock variables and many of the flow variables come from USDA, National Agricultural Statistics Service (NASS). NASS publishes the *Quarterly Hogs and Pigs* report with hog inventories by class, estimates of the number of sows farrowing that quarter, and the number of pigs weaned. NASS releases these reports in December, March, June, and September.

If pigs are slaughtered 6 months after birth, they were born sometime between the start of July of the previous year and the end of June of the current year. The Stillman-Weimar model took advantage of the quarterly report to shift the sows-farrowing, pigs-per-litter, and pigs-weaned equations so that the farrowing numbers aligned with the slaughter year rather than the calendar year. This approach to shifting the report numbers was used in the DBLM. For example, the total sows farrowing in 2020 in the DBLM is the sum of June–August 2019, September–November 2019, December 2019–February 2020, and March–May 2020. If hogs take 6 months to reach slaughter weight, some hogs born early in the "farrowing year" (for example, many of those born in June of the previous year) will be slaughtered in the previous calendar year.

Sows Farrowing is the total number of sows in a June–May year to give birth to piglets. The number of sows farrowing is an indicator of the hog and pork sector's production potential. *Sows Farrowing* is a function of lagged hog net returns as defined in equation HR, below. Equation 16 is:

(16) $\Delta Sows\ Farrowing_t = hog10 + hog11 * Real\ Hog\ Net\ Returns_{t-1} + hog12 * Real\ Hog\ Net\ Returns_{t-2} + \mu_t$

The symbol Δ stands for change from the previous year. The $hog11$ and $hog12$ coefficients are expected to be positive. Equation 16 shows that the number of sows will expand if hog production is profitable; alternatively, in years when hog production is unprofitable, the number of sows declines.

The *Hog Net Returns* function from the Stillman-Weimar model is:

(HR) $Hog\ Net\ Returns_t = 0.929 * Barrow\ and\ Gilt\ Price_t - 0.117 * PPI_t$
$- 0.117 * Wage_t - 6.347 * Corn_t - 0.060 * SBOM_t$

The *Barrow and Gilt Price* is the base lean hog price reported in the *WASDE* and LDP reports. See the data appendix for details on the source of this price. The hog net return formula is then divided by the CPI to determine the *Real Hog Net Returns*.

Coefficient estimates for equation 16 are in table 15.

Table 15
Sows farrowing equation, 1,000 head

Variable	Coefficient
Intercept	−155.528
Lag (Real hog net returns)	10.087
Lag 2 (Real hog net returns)	10.021

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The coefficients indicate that as the *Real Hog Net Returns* increase by \$1 in 1 year, the number of sows farrowing will increase by slightly more than 10,000 head in the 2 following years.

Pigs per Litter is the number of piglets weaned in each litter. *Pigs per Litter* has steadily increased for many years. Therefore, *Pigs per Litter* is a function of a time trend.

(17) $Pigs\ per\ Litter_t = hog50 + hog51 * Trend + \mu_t$

Coefficients estimates for equation 17 are in table 16.

Table 16
Pigs per litter equation, 1,000 head

Variable	Coefficient
Intercept	7.736
Trend	0.092

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

The positive *trend* coefficient indicates that since 1990, the average number of pigs per litter increased by approximately 0.09 per year.

Pig Crop is the total number of piglets born in a given year. *Pig Crop* is an identity equal to the number of *Sows Farrowing* times *Pigs per Litter*. This is an identity in the DBLM, equation (HG1):

(HG1) $Pig\ Crop_t = Sows\ Farrowing_t * Pigs\ per\ Litter_t$

FI *Barrow and Gilt Slaughter* is the total number of barrows and gilts slaughtered in FI plants. *Barrow and Gilt Slaughter* accounts for the majority of pork production. In 2017, barrows and gilts were 97 percent of the total hogs slaughtered. *Barrow and Gilt Slaughter* is a function of the *Pig Crop* and the *FI Ratio*. The *FI Ratio* for the hog equations is federally inspected slaughter of all hogs divided by the commercial slaughter of all hogs. The version of *FI Ratio* (cattle or hogs) is obvious within the context of the equations. In recent years, federally inspected hogs accounted for 99.5 percent of all commercial hog slaughter.

(18) $Barrow\ and\ Gilt\ Slaughter_t = hog20 + hog21 * Pig\ Crop_t * FI\ Ratio_t + \mu_t$

Coefficient estimates for equation 18 are in table 17.

Table 17
Federally inspected (FI) barrow and gilt slaughter, 1,000 head

Variable	Coefficient
Intercept	–1,286.020
Pig crop * FI ratio	0.955

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

The *Hog Net Returns* formula implies that as barrow and gilt prices increase or costs decrease, net returns increase. Equation 16 implies that higher net returns lead to more sows farrowing. More sow farrowing means a larger *Pig Crop* (equation 17) and identity HG1. Equation 18 implies a larger *Pig Crop* produces more *Barrow and Gilt Slaughter*.

Sow Slaughter is the total number of sows slaughtered in FI facilities in a given year. It is a function of *Sows Farrowing* and the *FI Ratio*.

(19) $Sow\ Slaughter_t = hog30 + hog31 * Sows\ Farrowing_t * FI\ Ratio_t + \mu_t$

Coefficient estimates for equation 19 are in table 18.

Table 18
Federally inspected (FI) sow slaughter, 1,000 head

Variable	Coefficient
Intercept	–234.696
Sows farrowing * FI ratio	0.298

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Boar Slaughter is the total number of boars slaughtered in federally inspected facilities in a given year. It is a function of *Sows Farrowing*.

(20) $Boar\ Slaughter_t = hog40 + hog41 * Sows\ Farrowing_t * FI\ Ratio_t + \mu_t$

Coefficient estimates for equation 20 are in table 19.

Table 19
Federally inspected (FI) boar slaughter, 1,000 head

Variable	Coefficient
Intercept	–1,796.940
Sows farrowing * FI ratio	0.191

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Coefficients indicate that larger numbers of *Sows Farrowing* are associated with greater sow and boar slaughter.

The last hog equation estimates the average carcass weight of commercial hogs. Hog carcass weights trended upward for years, so the *Hog-Carcass Weight* equation is driven by a time trend.

(21) $Hog\ Carcass\ Weight_t = hog60 + hog61 * Trend_t$

Coefficient estimates for equation 21 are in table 20.

Table 20
Average hog carcass weights, pounds per head

Variable	Coefficient
Intercept	179.887
Trend	1.195

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Estimates of equation 21 imply the average carcass weights of hogs increased by nearly 1.2 pounds per year.

The last pork equations are identities that calculate *FI Hog Slaughter, Commercial Hog Slaughter, Commercial Pork Production, Total Pork Disappearance*, and *Per Capita Pork Disappearance*:

(HG2) $FI\ Hog\ Slaughter_t = Barrow\ and\ Gilt\ Slaughter_t + Sow\ Slaughter_t + Boar\ Slaughter_t$

(HG3) $\dfrac{FI\ Hog\ Slaughter_t}{Commercial\ Hog\ Slaughter_t} = FI\ Ratio_t$

(HG4) $Commercial\ Pork\ Production_t = (Commercial\ Hog\ Slaughter_t) * (Hog\ Carcass\ Weight_t)$

(HG5) $Pork\ Starting\ Stocks_t + Pork\ Imports_t + Commercial\ Pork\ Production_t + Farm\ Pork\ Production_t$
   $= Pork\ Starting\ Stocks_{t+1} + Pork\ Exports_t + Pork\ Disappearance_t$

(HG6) $Per\ Capita\ Pork\ Disappearance_t = Pork\ Disappearance_t\ /\ Population_t$

In HG2 and HG3, the hog numbers are measured in 1,000 heads. HG5 and HG6 are simplified equations that calculate millions of pounds of pork production; HG6 estimates pounds of pork per capita.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
USDA, Economic Research Service

The Chicken/Broilers Sector

Broiler production is the fastest process in the model. It begins with breeders, the hens that lay fertilized eggs that become broiler chicks. Generally, laying hens begin producing eggs around 24 weeks of age and can lay efficiently for 40 weeks per cycle, about 150–180 eggs per year. Eggs are collected and placed into incubators for hatching in about 21 days. Upon hatching, the chicks are processed and moved to grow-out farms within 12 hours. It then takes about 5 weeks for the broiler to reach market weight.

Equations

The broiler *Hatchery Supply* flock is the total number of broiler-type laying hens each year. This number represents production potential. The *Hatchery Supply* flock is a function of the previous year's *Hatchery Supply* flock.

$$(22) \qquad Hatchery\ Supply_t = br11 * Hatchery\ Supply_{t-1} + \mu_t$$

The coefficient estimate for equation 22 is in table 21.

Table 21
Broiler hatchery flock, 1,000 birds

Variable	Coefficient
Lag (Hatchery supply)	1.012

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Equation 22 implies that the broiler flock tends to grow at approximately 1.2 percent per year.

Broiler Chicks Hatched is the total number hatched each year. It is a function of the *Hatchery Supply* flock multiplied by the number of *Eggs per Layer*. The *Eggs per Layer* is divided by 100 because the data are reported as eggs per 100 layers. *Broiler Chicks Hatched* is also a function of *Real Broiler Net Returns* and a *Time Trend*.

$$(23) \qquad Chicks\ Hatched_t = br20 + br21 * Hatchery\ Supply_t * \left(\frac{Eggs\ per\ Layer_t}{100} \right) + br22 * Real\ Broiler\ Net\ Returns + br23 * Trend + \mu_t$$

Coefficient estimates for equation 23 are in table 22.

Table 22
Broiler chicks hatched, 1,000 birds

Variable	Coefficient
Intercept	1,751,944.000
(Hatchery supply) *(Eggs per layer)	0.576
Real broiler net returns	6,881.954
Trend	41,629.440

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Broiler Net Returns was adopted from the Stillman-Weimar model and is a function of the wholesale price for broilers, corn prices, the SBOM price, and the CPI:

(BR) $Broiler\ Net\ Returns_t = Wholesale\ Broiler\ Price_t - 0394 * CPI_t - 3.755 * Corn_t - 0.394 * SBOM_t$

The *Broiler Net Returns* formula is then divided by the CPI to estimate the *Real Broiler Net Returns*. The *Wholesale Broiler Price* is measured in dollars per hundredweight (cwt). See appendix A for its source and definition.

Broiler net returns are higher when the wholesale price of broilers is higher and lower when input costs are higher. A \$1-per-cwt real increase in the broiler net returns increases chicks hatched by nearly 7 million per year. The trend coefficient implies that the broiler chicks hatched tends to increase by nearly 42 million per year.

Broiler Slaughter is the total number of broilers slaughtered each year. *Broiler Slaughter* is a function of the number of *Broiler Chicks Hatched*.

(24) $Broiler\ Slaughter_t = br31 + br32 * Chicks\ Hatched_t + \mu_t$

Coefficient estimates for equation 24 are in table 23.

Table 23
Broiler slaughter, 1,000 birds

Variable	Coefficient
Intercept	−14,156.800
Broiler chicks hatched	0.935

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

As expected, the coefficient for *Broiler Chicks Hatched* is less than 1, primarily reflecting death loss between hatching and slaughter.

Broiler dressed weight is a function of a time trend and the equation is:

(25) $Broiler\ Weight_t = br40 + br41 * Trend_t + \mu_t$

Coefficient estimates for equation 25 are in table 24.

Table 24
Average dressed weight of broilers, pounds

Variable	Coefficient
Intercept	3.060
Trend	0.058

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

As is the case for cattle and hogs, the average weights for broilers increased over time. The trend coefficient in equation 25 implies that these weights have increased at approximately 0.06 pounds per year.

Three identity equations close out the broiler equations. The first multiplies average *Broiler Weight* by *Broiler Slaughter* to obtain broiler meat production. The next balances supply and utilization to calculate *Broiler Disappearance*. The last divides *Broiler Disappearance* by *Population* to determine *Per Capita Disappearance*. Unlike cattle or hogs, official Government data does not include non-federally inspected (NFI) poultry production.

(BR1) $Broiler\ Production_t = (Broiler\ Slaughter_t) * (Broiler\ Weight_t)$

(BR2) $Broiler\ Starting\ Stocks_t + Broiler\ Imports_t + Broiler\ Production_t =$
$Broiler\ Starting\ Stocks_{t+1} + Broiler\ Exports_t + Broiler\ Disappearance_t$

(BR3) $Per\ Capita\ Broiler\ Disappearance_t = Broiler\ Disappearance_t\ /\ Population_t$

As is the case for other species, broiler trade and stocks are exogenous to the DBLM.

The Turkey Sector

Turkey production is generally like broilers but takes a few extra weeks. The process starts with breeders that lay fertilized eggs. Eggs are collected and placed into incubators where they hatch after 28 days. Poults are then processed and delivered to grow-out farms within 12 hours. On average, it takes hens 12–14 weeks, and toms 16–19 weeks to reach market weight.

Equations

The Stillman-Weimar model used turkey net returns in its supply equations. It was possible to recreate their net return formula; however, the Stillman-Weimar supply equations performed poorly using the DBLM database. The specification selected for the DBLM uses a ratio of the wholesale price of turkey to the cost of turkey feed. Analysts involved in creating the *WASDE* and LDP reports developed standard feed formulas for livestock and poultry production. The turkey standard feed ration is assumed to be 70 percent corn and 30 percent SBOM. The DBLM calculated the cost of 100 pounds of standard turkey feed assuming this ration.

NASS provides data on the number of turkey eggs in incubators in its monthly *Turkey Hatchery* report. The *Eggs* in incubators is a function of the past year's turkey-to-feed ratio, last year's eggs, an intercept, and a time trend. The equation is:

$$(26) \quad Eggs_t = tk10 + tk11 * Trend + tk12 \; \frac{Wholesale \; Turkey \; Price_{t-1}}{Turkey \; Feed \; Cost_{t-1}} + tk13 * Eggs_{t-1} + \mu_t$$

Coefficient estimates for equation 26 are in table 25.

Table 25
Eggs in incubators, 1,000 eggs

Variable	Coefficient
Intercept	153,098.839
Trend	–1,276.300
Lagged wholesale turkey price/feed cost ratio	2,786.910
Lagged eggs	0.553

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The positive coefficient on the *Lagged Wholesale Turkey Price/Feed Cost Ratio* implies that the number of turkey eggs tends to increase next year when this year's turkey-feed price ratio is higher. A large number of turkey eggs this year is associated with larger numbers next year. The negative term for the trend implies that the number of turkey eggs would tend to decline over time if the price-feed ratio were constant.

Net Poults Placed is the total number of poults placed in growing houses each year. It is a function of *Eggs* in incubators, and the equation is:

$$(27) \quad Poults \; Placed_t = turk20 + turk21 * Eggs_t + \mu_t$$

Coefficient estimates for equation 27 are in table 26.

Table 26
Net poults placed, 1,000 head

Variable	Coefficient
Intercept	69,191.810
Eggs	0.604

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Turkey Slaughter is the total number of turkeys slaughtered each year. It is a function of net *Poults Placed*, and the equation is:

$$(28) \qquad Turkey\ Slaughter_t = turk30 + turk31 * Poults\ Placed_t + \mu_t$$

Coefficient estimates for equation 28 are in table 27.

Table 27
Turkey slaughter, 1,000 head

Variable	Coefficient
Intercept	−493.761
Poults placed	0.889

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Starting with equation 26, increases in turkey prices or decreases in feed costs lead to increased numbers of turkey eggs. Higher numbers of turkey eggs lead to more poults placed. More poults lead to higher numbers of turkeys slaughtered.

As is the case with the other species, turkey dressed weights trended upward over the years. The turkey weight equation is a function of a time trend:

$$(29) \qquad Turkey\ Weight_t = turk40 + turk41 * Trend_t + \mu_t$$

Coefficient estimates for equation 29 are in table 28.

Table 28
Average dressed weight of turkeys, pounds

Variable	Coefficient
Intercept	16.739
Trend	0.315

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

The estimate indicates that the average dressed weight of turkeys increased by over 0.3 pounds per year over the 30-year period.

As is the case for broilers, three identity equations close out the turkey supply equations: total production, total disappearance, and per-capita disappearance identities. As is the case for the other species, turkey trade and stocks are exogenous to the DBLM.

(TK1) $Turkey\ Production_t = (Turkey\ Slaughter_t) * (Turkey\ Weight_t)$

(TK2) $Turkey\ Starting\ Stocks_t + Turkey\ Imports_t + Turkey\ Production_t =$
$Turkey\ Starting\ Stocks_{t+1} + Turkey\ Exports_t + Turkey\ Disappearance_t$

(TK3) $Per\ Capita\ Turkey\ Disappearance_t = Turkey\ Disappearance_t / Population_t$

The quantities in TK1 and TK2 are millions of pounds; TK3 calculates pounds per capita.

Price Transmission

The demand section of the Domestic Baseline Livestock Model sets the retail prices for beef, pork, chicken, and turkey. These retail prices are then used to determine wholesale and farm-level prices through a set of price transmission equations. The sows-farrowing equation (equation 17) uses a change variable. In this case, the symbol Δx_t stands for the change in x between years t and t1, or $\Delta x_t = x_t - x_{t-1}$.

Equations

Price transmission equations are all change equations. Prices are deflated by the CPI to calculate real prices. In the discussion and equations to follow, the prices are real prices. The livestock and wholesale meat prices used in the DBLM come from USDA's Agricultural Marketing Service (AMS). More detail on sources of the nominal prices is in appendix A. All livestock and wholesale prices are expressed in dollars per hundredweight (cwt). The retail prices used in the price transmission equations are also expressed in dollars per cwt, which is equivalent to cents per pound.

The beef and cattle price transmission equations include values of wholesale beef. The DBLM has two wholesale beef values. The first is the *Boxed Beef* price, which in the database is the AMS-negotiated Choice beef cutout. Choice beef cutout is a weighted average of meat cuts produced by a Choice steer. It is expressed in dollars per cwt of carcass weight. The *Boxed Beef* equation is:

(30) $\Delta Boxed\ Beef_t = Pr10 + Pr11 * \Delta Retail\ Price\ Beef_t + \mu_t$

All price transmission equations have an intercept. The intercept in a change equation provides a year-over-year change in price even if no other factors change. Coefficient estimates for equation 30 are in table 29.

Table 29
Change in boxed beef equation, real dollars per cwt

Variable	Coefficient
Intercept	–0.510
ΔRetail price beef	0.410

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The intercept in the boxed beef equation implies that the real value of boxed beef tends to decline by $.51 per cwt per year. At the 2020 price level, a real price decline of $.51 translates to a nominal price decline of $1.32 per cwt.

Steers and heifers produce boxed beef. Cow meat is used to produce ground and processed beef: hamburger, bologna, franks, etc. The wholesale cow beef price used in the DBLM is the 90-percent lean trim price. This is a boneless, lean beef product. The lean trim price equation is:

(31) $\Delta Lean\ Trim_t = Pr20 + Pr21 * \Delta Retail\ Price\ Beef_t + \mu_t$

Coefficient estimates for equation 31 are in table 30.

Table 30
Change in lean trim, real dollars per cwt

Variable	Coefficient
Intercept	–1.010
ΔRetail price beef	0.500

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

A $1-per-cwt increase in the retail price of beef increases the lean trimmings price by $0.50 per cwt. The intercept implies the real price of lean trim tends to decline by over $1 per cwt per year.

The *WASDE* and LDP reports use an all-grades, live steer price from AMS. This is the price currently used in the DBLM. The *Steer Price* is a function of the *Boxed Beef Price* and the equation is:

$$(32) \qquad \Delta Steer\ Price_t = Pr30 + Pr31 * \Delta Boxed\ Beef\ Price + \mu_t$$

Coefficient estimates for equation 32 are in table 31.

Table 31
Change in the steer price, dollars per cwt

Variable	Coefficient
Intercept	–0.220
ΔBoxed beef price	0.670

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The boxed beef price is in dollars per cwt carcass weight; the steer price is in dollars per cwt live weight. When calculating beef price spreads, ERS assumes a steer produces 63 pounds of carcass per 100 pounds of live weight. Given that yield, a $1 increase in the value of a carcass translates to a $0.63 increase in the live value. The estimated price transmission is slightly higher than the carcass-to-live ratio.

The *Cow Price* is the annual average price for slaughter cows. The *Cow Price* is a function of the *Lean Trim* price:

$$(33) \qquad \Delta Cow\ Price_t = Pr50 + Pr51 * \Delta Lean\ Trim_t + \mu_t$$

Coefficient estimates for equation 33 are in table 32.

Table 32
Change in the cow price, dollars per cwt

Variable	Coefficient
Intercept	−0.250
ΔLean trim	0.370

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Both cow and steer prices increase when the value of their output increases. The cow price response to lean trim changes is smaller than that of steer prices to the boxed-beef value. The smaller response for cows would be expected. The cow output is boneless; the steer output is a carcass-weight price. If everything else were equal, price transmission from boneless to live would be less than price transmission from carcass to live. In addition, an average cow's meat yield per pound of live animal is lower than that of an average steer.

The *Feeder Steer Price* is compiled from AMS feeder-cattle reports by USDA and presented in the LDP. The *Feeder Steer Price* is a function of the *Steer Price* and *Feed Cost*. To develop *Feed Costs,* the standard *WASDE* formula for 100 pounds of steer feed is 66.67 pounds of corn, 28.83 pounds of roughage, and 4.50 pounds of SBOM. For the purposes of the DBLM, roughage was priced using the price of hay.

$$(34) \qquad \Delta Feeder\ Steer\ Price_t = Pr60 + Pr61 * \Delta Steer\ Price + Pr62 * \Delta Feed\ Cost + \mu_t$$

Coefficient estimates for equation 34 are in table 33.

Table 33
Change in the feeder steer price, dollars per cwt

Variable	Coefficient
Intercept	−0.230
ΔSteer price	1.660
ΔFeed cost	−0.270

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

A $1 increase in the steer price raises the feeder steer price by $1.66. Typically, feeder steer prices are higher than prices for fed steers. Higher feed costs make feeding cattle less profitable and lowers the prices of feeder steers.

The *Barrow and Gilt Price* is the annual average of the national base 51–52 percent-lean price. The *Barrow and Gilt Price* is a function of the *Retail Pork Price:*

$$(35) \qquad \Delta Barrow\ and\ Gilt\ Price_t = Pr70 + Pr71 * \Delta Retail\ Pork\ Price_t + \mu_t$$

Coefficient estimates for equation 35 are in table 34.

Table 34
Change in the barrow and gilt price, dollars per cwt

Variable	Coefficient
Intercept	−0.620
ΔRetail pork price	0.250

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Equation 35 estimates imply that one-fourth of the change in the retail price of pork is transmitted to the price of hogs. The negative value for the intercept estimate implies that real hog prices would tend to decline year-over-year, even if the retail price of pork were unchanged.

The *Broiler Price* is the annual average of the national composite price. The *Broiler Price* is a function of the *Retail Chicken Price*:

(36) $\Delta Broiler\ Price_t = Pr80 + Br81 * \Delta Retail\ Chicken\ Price_t + \mu_t$

Coefficient estimates for equation 36 are in table 35.

Table 35
Change in the wholesale broiler price, dollars per cwt

Variable	Coefficient
Intercept	0.110
ΔRetail chicken price	0.580

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Both the retail and wholesale broiler prices are for the whole bird; 1 pound of wholesale bird produces 1 pound of retail bird. Only 0.580 percent of retail broiler price changes are reflected in the wholesale prices.

The *Turkey Price* is the annual average 8–16-pound hen price. The *Turkey Price* is a function of *Retail Turkey Price* and is estimated as:

(37) $\Delta Turkey\ Price_t = Pr90 + Br91 * \Delta Retail\ Turkey\ Price_t + \mu_t$

Coefficient estimates of equation 37 are in table 36.

Table 36
Change in the wholesale turkey price, dollars per cwt

Variable	Coefficient
Intercept	0.170
ΔRetail turkey price	0.390

Note: cwt = hundredweight.

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Just like broilers, wholesale and retail turkeys are whole, frozen birds. One pound of wholesale turkey translates into 1 pound of retail turkey. Less than 40 cents of every dollar increase in the retail turkey price is passed back to the wholesale price.

Discussion and Conclusions

The Domestic Baseline Livestock Model has three sets of equations. Because the Stillman-Weimar model served as the standard for the livestock model, this work specifies production equations like those in the previous work. With two exceptions, the DBLM matches the general structure of the Stillman-Weimar model albeit with different parameter estimates. The exceptions are the equations for the January 1 inventory of bulls and the turkey eggs equations. New equation structures and retail price data were used in specifying the demand and price transmission equations.

Appendix B compares DBLM model predictions for the endogenous variables to their actual values. Many DBLM equations use variables from previous years; these variables are used in appendix B, which offers projections between 1991 and 2019. The 2019 data were not used to estimate the DBLM.

When developing projections for the Baseline, USDA personnel do not have the actual previous year's data for most of the years projected. In these exercises, they use the previous year's projected values. Appendix C shows simulations running 1991–2019 using lagged projections rather than lagged actual values. Appendix C compares the simulated and actual values for these variables. The supplies of all four species are functions of feed costs. Appendix C also shows simulations with lower feed costs.

The simulations in appendix B are one-step-ahead forecasts. The 1991 forecast is based on lagged endogenous from 1989 and 1990; that is data known the prior year. The 1991 simulations in appendix C also use 1989 and 1990 data. However, the 1992 simulation replaces actual 1991 values with the 1990 simulations. The 1992 simulation is a two-step-ahead forecast, the 1993 simulation is three-steps-ahead, and so forth.

The fits of the one-step-ahead forecasts vary depending on the variables. The total consumption and production forecasts for each of the four species tend to fit better than the price forecasts. The multi-step-ahead forecasts in appendix C are less accurate than the one-step-ahead forecasts. The multi-step-ahead forecasts are expected to be less accurate because the one-step-ahead forecasts use actual, lagged values of the data rather than forecasts of the data.

Potential for Future Work

The Domestic Baseline Livestock Model's equations are estimated using data up to 2018. It would be desirable to update the estimates in the future. Major disruptions to markets in 2020 were associated with the Coronavirus (COVID-19) pandemic. It is an open question whether the data from 2020 are representative of typical market conditions and how one would deal with this anomalous data.

Expanding the number of equations in the DBLM could be valuable. The DBLM is focused on domestic U.S. conditions and does not attempt to explain trade. Trade is determined in other models through the linker system maintained by ERS. The lack of trade equations in the DBLM is not a problem for baseline creation. An expanded version of the DBLM with endogenous trade could be useful for other types of analysis.

Many reviewers noted the use of "net calves" in the cattle-supply equations. The "net calves" identity makes most sense if all cattle imports and exports were calves, which is not the case. Reviewers also noted that none of the hog supply equations include hog imports or exports. Changes in how the DBLM treats hog and cattle trade could improve its performance.

An Emerging Problem

The Domestic Baseline Livestock Model's demand equations use whole, retail turkey prices as reported by BLS. The BLS monthly data release has not reported a turkey price since February 2020. So, it might be necessary to find other estimates of the retail turkey price. Another solution may be to allow the DBLM equations to solve for a retail turkey price given the other variables and use that price solution as the retail turkey price.

Shifting the demand specification from a retail-level to a wholesale-level demand may have value. Hahn and Mathews (2007) provide an example of a wholesale-level meat demand system, which includes boxed beef; cow and bull meat priced as lean trimmings; pork; chicken; and turkey. A system that splits steer and heifer beef from cow and bull beef might provide better forecasts and simulations of the market.

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Appendix A: Data Sources

The data used in the Domestic Baseline Livestock Model is U.S. Government data. When the study was started, much of the model data were extracted from historical *WASDE* or LDP reports. This appendix discusses the initial sources of the model data. Over the decades that the USDA produced *WASDE* and LDP reports, data sources changed, most often for prices. The appendix also highlights the current data sources.

Cattle inventory data comes from the annual January 1 *Cattle* report issued by NASS. The variables in the DBLM from the *Cattle* report are:

- Beef cow inventory
- Calf crop
- Steers larger than 500 pounds
- Other heifers larger than 500 pounds
- Heifers larger than 500 pounds kept for beef cow replacements
- Bulls larger than 500 pounds
- Calves smaller than 500 pounds

Hog inventory figures in the following categories are taken from the quarterly NASS reports titled *Hogs and Pigs*:

- Sows farrowing
- Pigs weaned
- Pigs per litter

Federally inspected cattle and hog slaughter data are available from Food Safety and Inspection Service reports. These are compiled in the monthly NASS report, *Livestock Slaughter*. The annual value used is a yearly sum of the monthly data. The data from this report in the DBLM are:

- Federally inspected steer slaughter
- Federally inspected heifer slaughter
- Federally inspected beef cow slaughter
- Federally inspected dairy cow slaughter
- Federally inspected bull slaughter
- Commercial cattle slaughter
- Commercial beef production
- Cattle slaughter weights
- Federally inspected barrow and gilt slaughter
- Federally inspected sow slaughter

- Federally inspected boar slaughter

- Commercial hog slaughter

- Average hog carcass weights

Inventory data in the following categories for the broiler sector may be obtained from the NASS *Chicken and Eggs* monthly reports:

- Broiler hatchery flock

- Chicks hatched

Inventory data in the following categories for turkeys may be obtained from the monthly NASS *Turkey Hatchery* report:

- Eggs in incubators

- Net poults placed

The number of birds slaughtered, poultry production, and average bird weights are from the monthly NASS *Poultry Slaughter Report*. This report is the source for:

- Broiler slaughter

- Average dressed weight of broilers

- Broiler production

- Turkey slaughter

- Turkey production

- Average dressed weight of turkeys

Livestock and Wholesale Prices

The initial source of livestock and wholesale prices in the Domestic Baseline Livestock Model is the USDA, Agricultural Marketing Service (AMS). The price reports for AMS data are identified by the report title and an AMS file name. The AMS file name may provide better search results than the title. Each of these prices comes from a separate report.

The steer price comes from *5 Area Monthly Weighted Average Direct Slaughter Cattle—Negotiated*, AMS 2685. The steer price used from this report is the live, free-on-board (FOB) total all grades price. The cow price is obtained from the *National Weekly Direct Cow and Bull Report–Negotiated Price*, AMS 2488. The price used is for cutter cows, 90-percent lean, 500 pounds and up. The feeder calf price is from the *Oklahoma National Stockyards Feeder Cattle—Oklahoma City, OK*, AMS 1280. The price used is for medium frame #1 feeder steers, 750–800 pounds.

Hog price data come from the report *National Daily Base Lean Hog Carcass Slaughter Cost*, AMS 2523. This report also has weekly and monthly average price estimates. The price used is the 51–52-percent base lean hog price. The USDA previously used live hog prices. The 51–52-percent lean hog price is a carcass-weight price. This price is transformed to a live weight price by multiplying the carcass weight price by 0.74, which is an estimate of the pounds of carcass produced by 1 pound of live hog.

The boxed beef value is the Choice beef cutout as reported in the *National Weekly Boxed Beef Cutout And Boxed Beef Cuts—Negotiated Sales*, AMS 2461. The lean trimmings price is taken from *National/Regional Weekly Boneless Processing Beef And Beef Trimmings—Negotiated Sales*, AMS 262. The price used is the national FOB plant fresh 90.

Whole broiler prices come from the *USDA Weekly National Whole Broiler/Fryer Report*, pywwholebroiler.pdf. This report has a monthly composite weighted average price for the previous month. Whole turkey prices are the monthly average prices for Grade A Frozen 8–16-pound hens from the report, *TURKEY: Weekly National Fresh and Frozen Whole Young Turkeys*.

Retail Price Data

The Choice beef and pork retail composites are from USDA, ERS. Current and historical data for these composites may be downloaded from the *ERS Meat Price Spread Data* webpage. Whole chicken and whole frozen turkey prices come from the BLS average price database. BLS retail chicken, turkey, and other animal product prices can also be downloaded from the *ERS Meat Price Spread Data* website.

Appendix B: Endogenous Variables and In-Sample Projections

The Domestic Baseline Livestock Model has 38 econometric equations and 15 identities. The model coefficients can be used to estimate and project 53 variables. This appendix shows 49 of these variables in the estimation period with the model's solutions or projections. Four of the identity equations transform total disappearance of a meat to per-capita disappearance. This appendix shows only per-capita disappearance.

The projected variables shown in this appendix can differ from the projected variables implied by the econometric equations. All of the econometric equations have random error terms. The solution to the equation is the value if the error term were 0. Many variables in the DBLM depend on other variables. For example, consider the calf-crop equation (equation 4), which is a function of the sum of dairy cows and beef cows. Equation 3 predicts the number of beef cows. The calf-crop prediction in the charts uses the beef cow inventory predicted by equation 3 rather than the actual number of beef cows. In this case, first solve for beef cows, then solve for the calf crop given the beef cow solution. There are cases where sets of variables are mutually dependent; one needs to find a solution for the whole set simultaneously.

In the charts to follow, the term "formula" denotes the DBLM solution; the term "actual" is, of course, the actual data. Sources are NASS and AMS data compiled by USDA, ERS; the formula data are calculated by the authors using the DBLM.

Figure B1
Retail beef prices
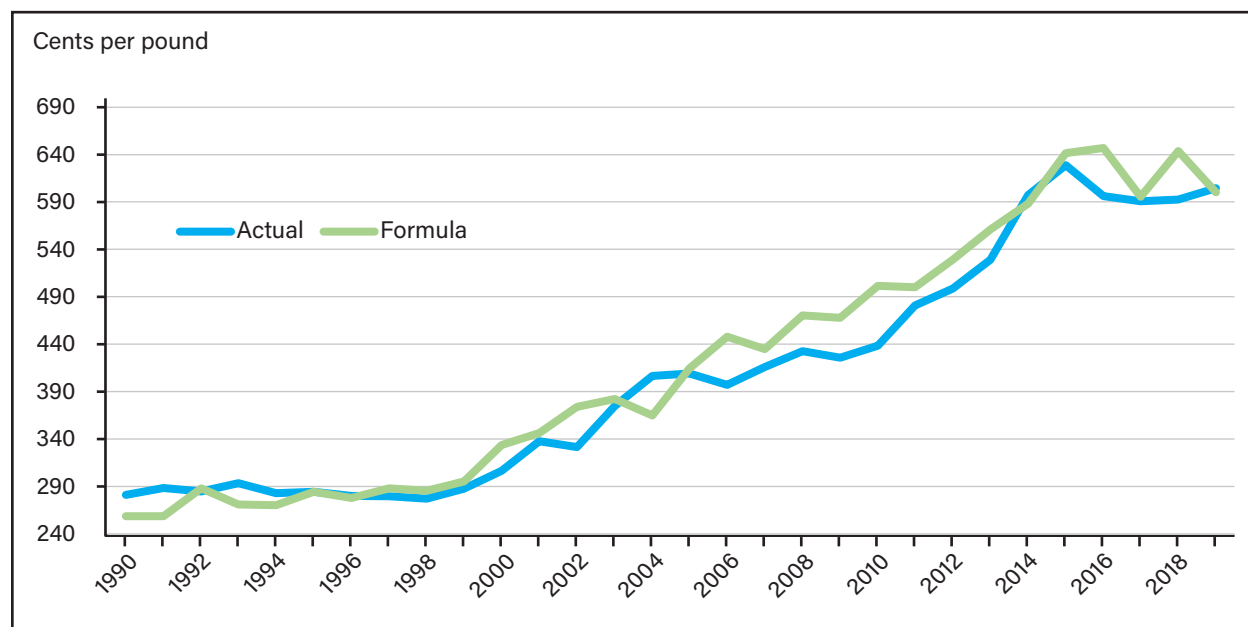
Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B2
Retail pork prices
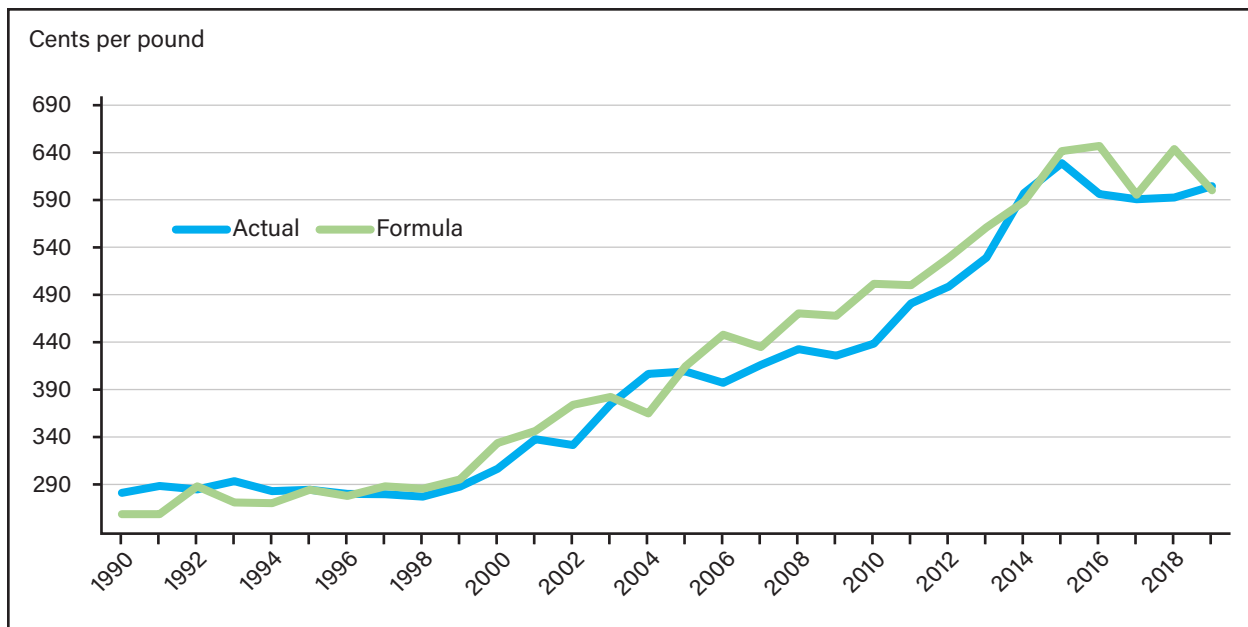
Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B3
Retail chicken prices
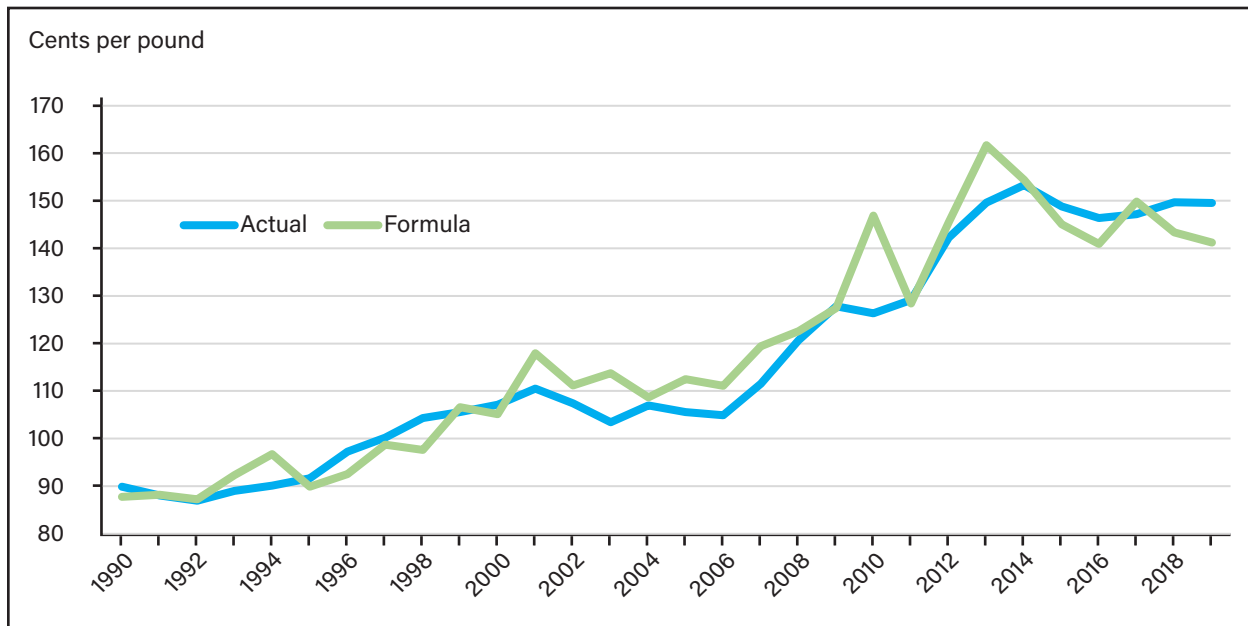
Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B4
Retail turkey prices
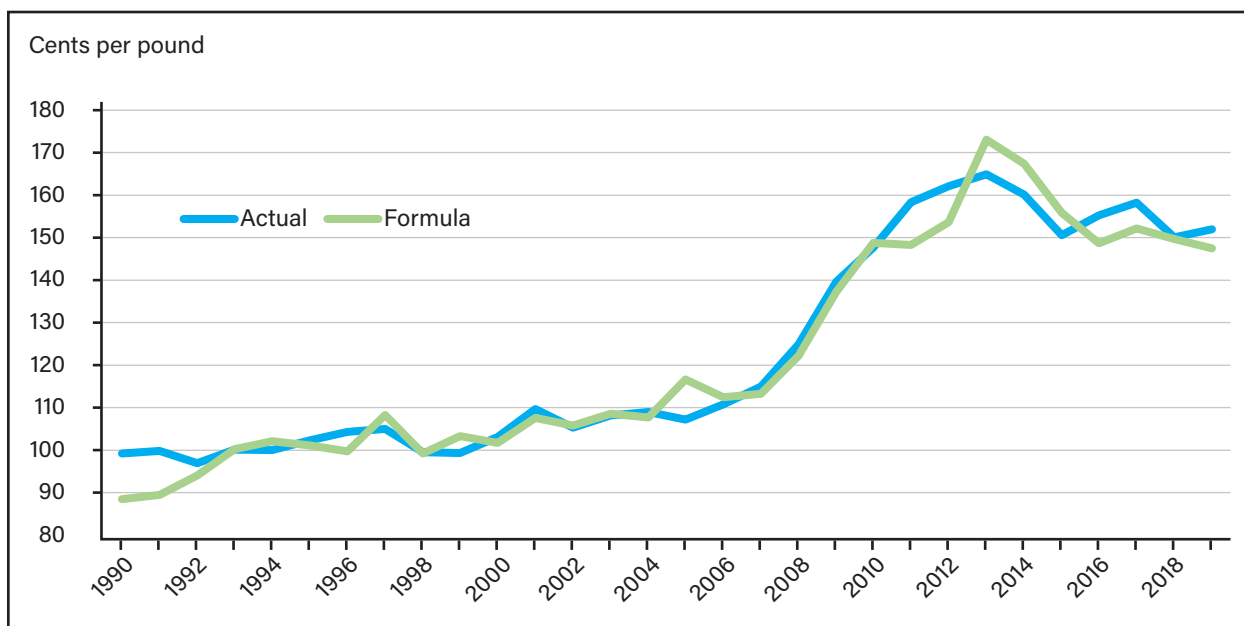
Cents per pound

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.
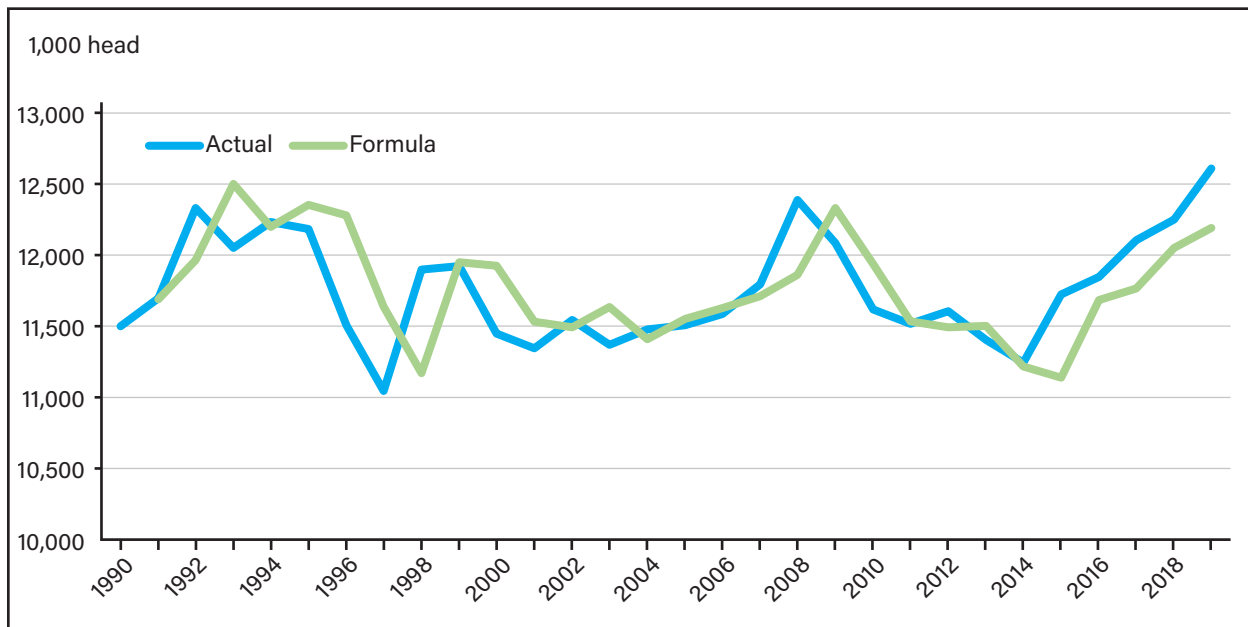
Figure B5
Beef consumption
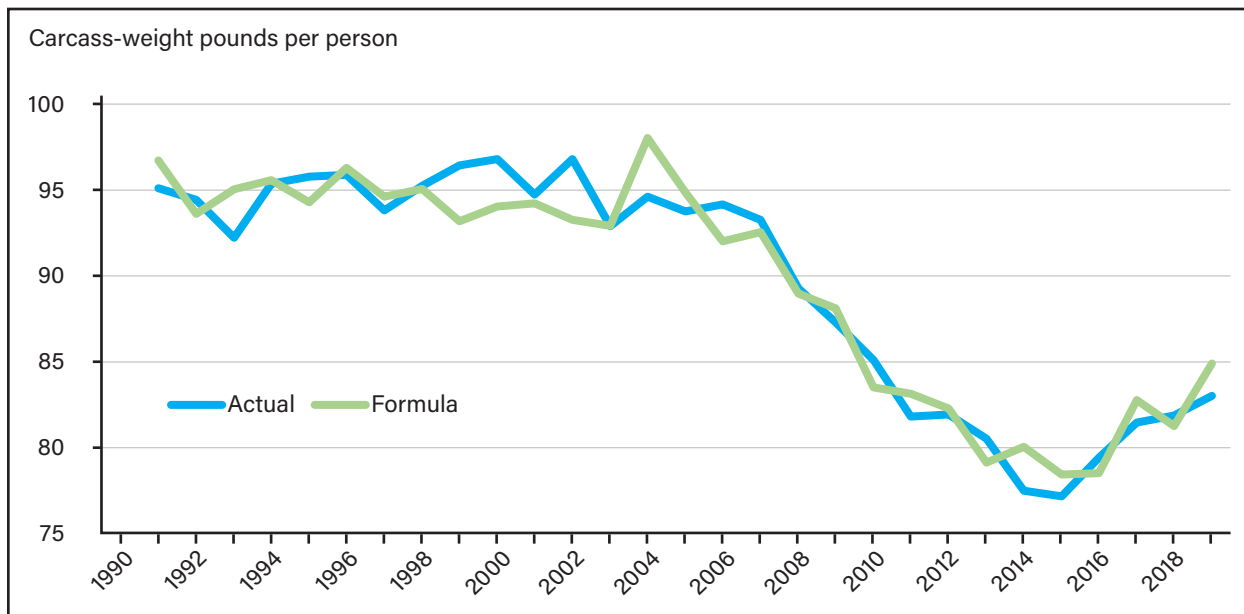
Carcass-weight pounds per person
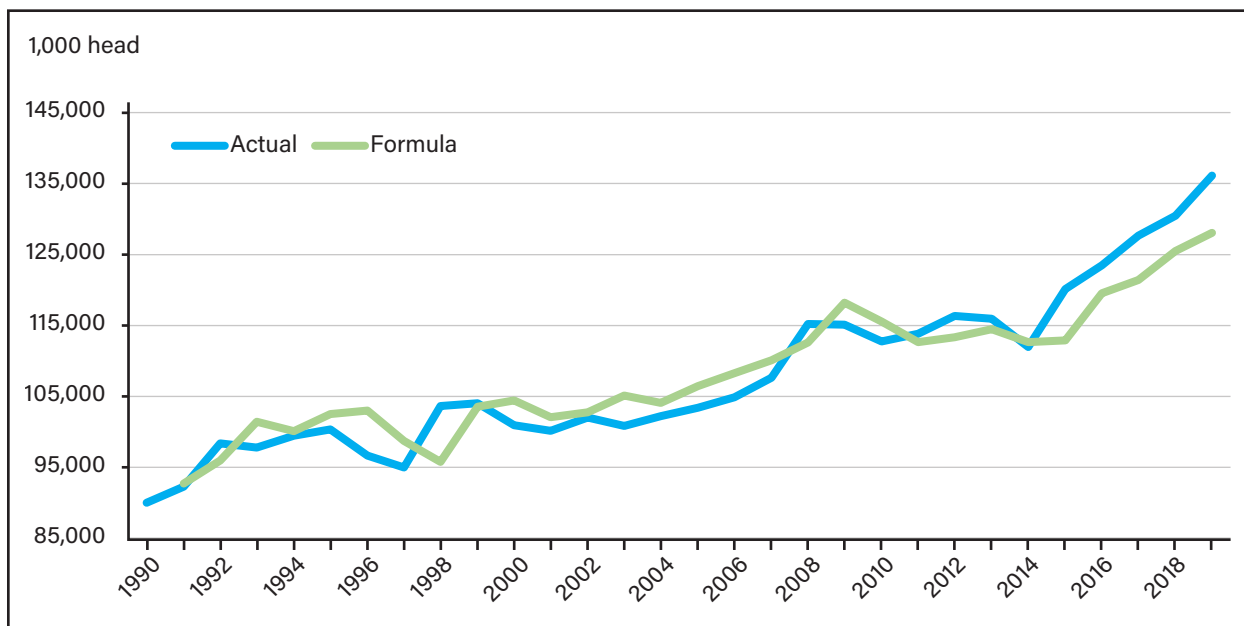

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
USDA, Economic Research Service

Figure B6
Pork consumption
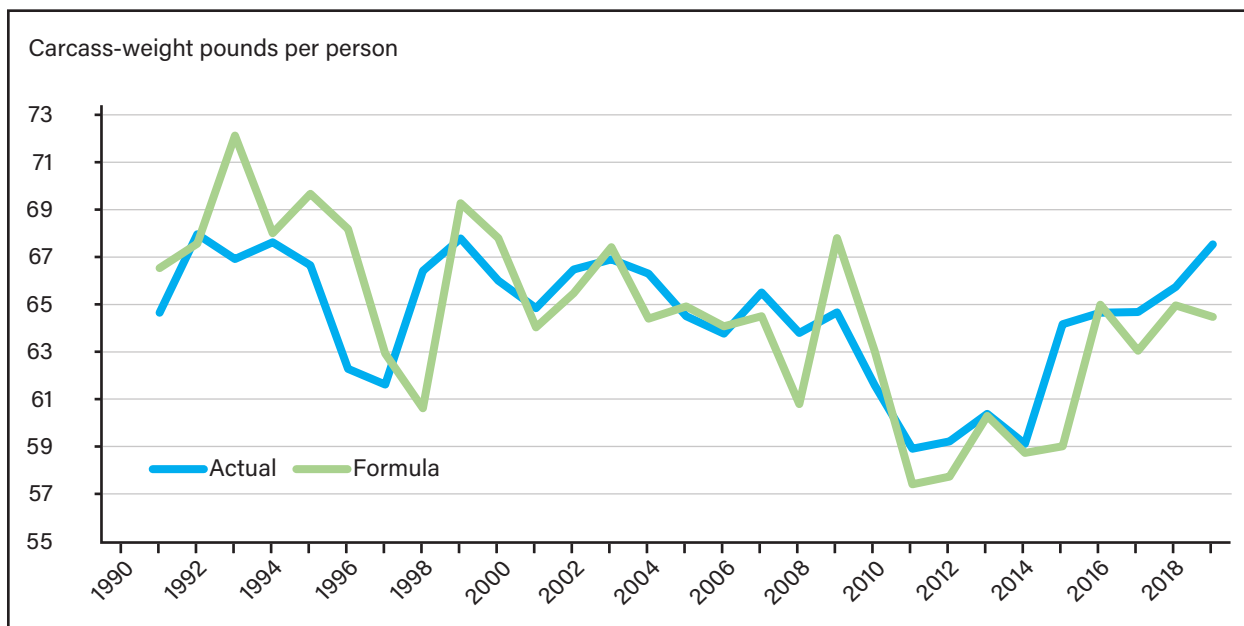
Carcass-weight pounds per person

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
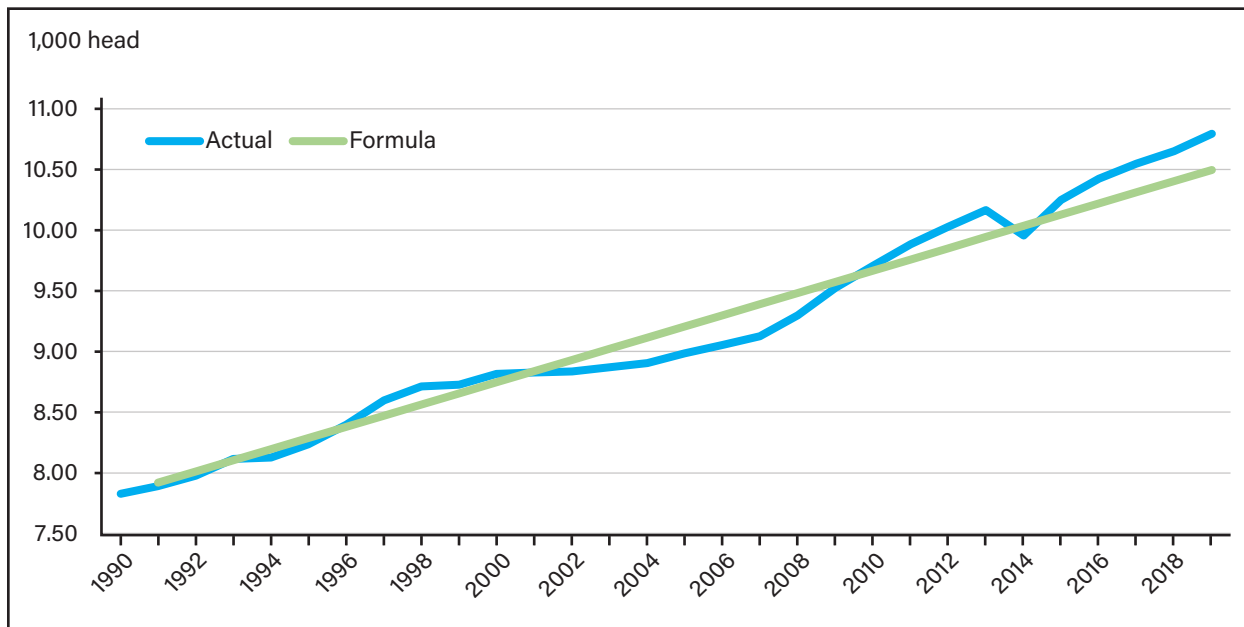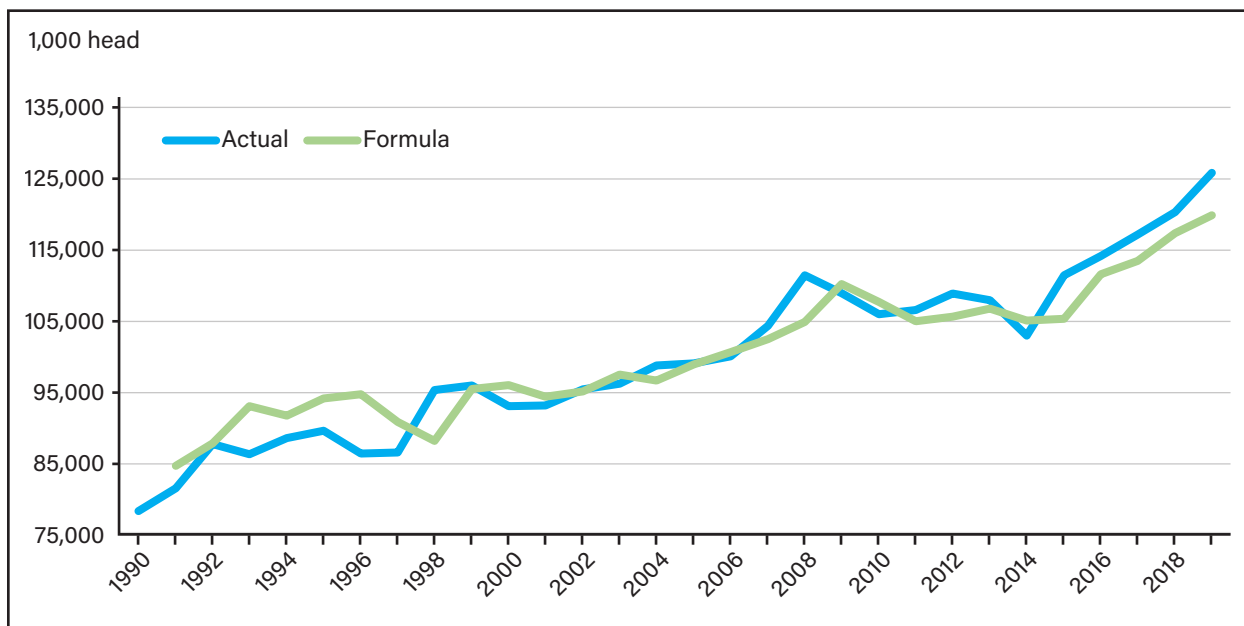
Figure B7
Broiler consumption
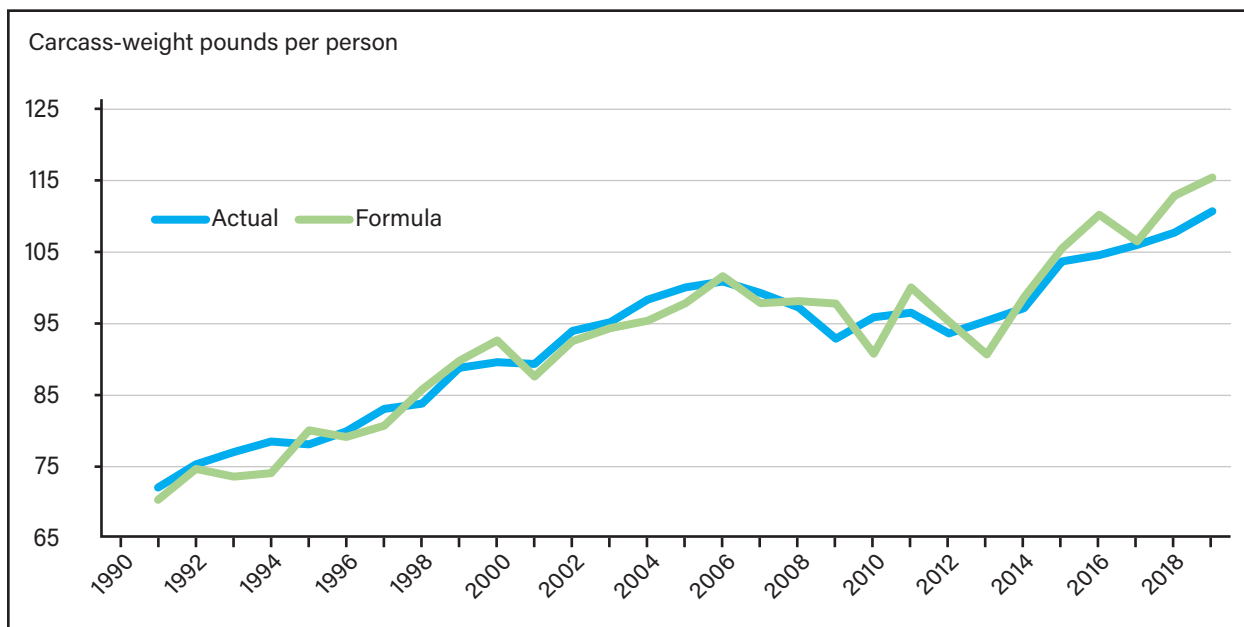
Carcass-weight pounds per person

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
USDA, Economic Research Service

Figure B8
Turkey consumption
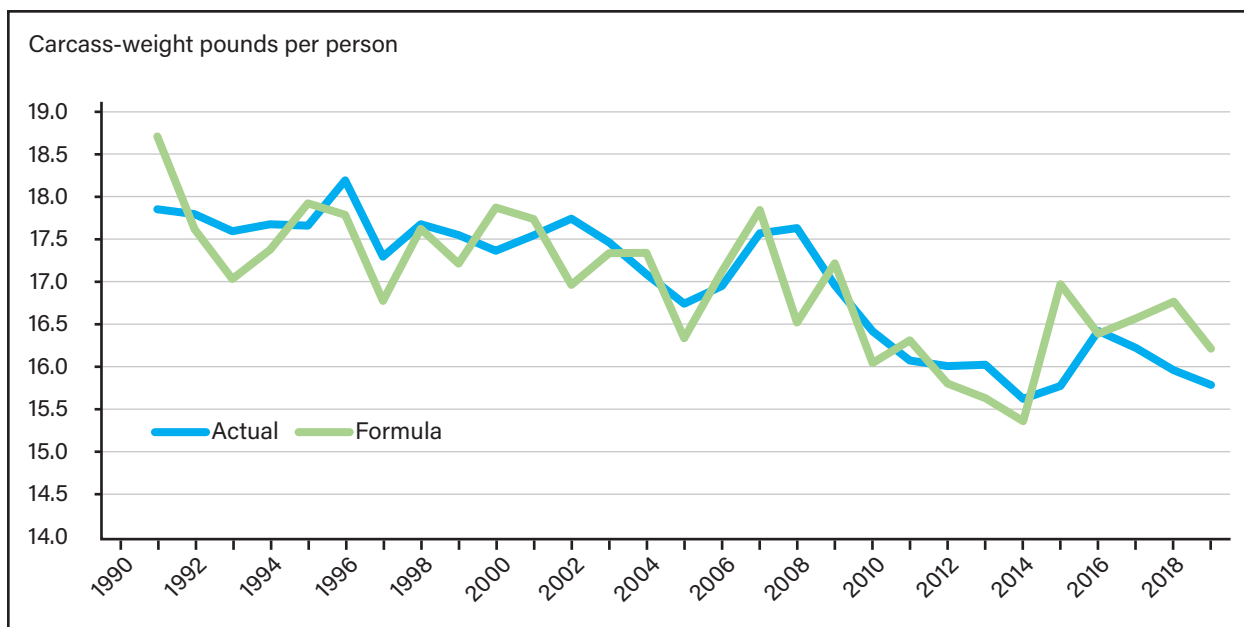
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
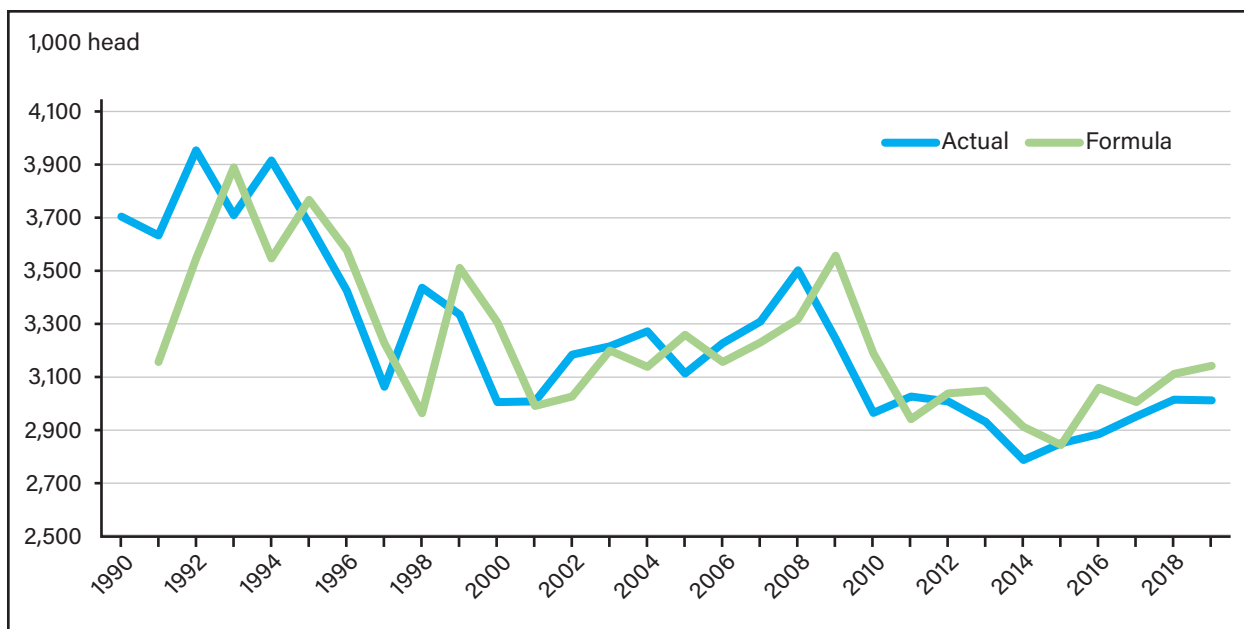
Figure B9
Beef cow inventory
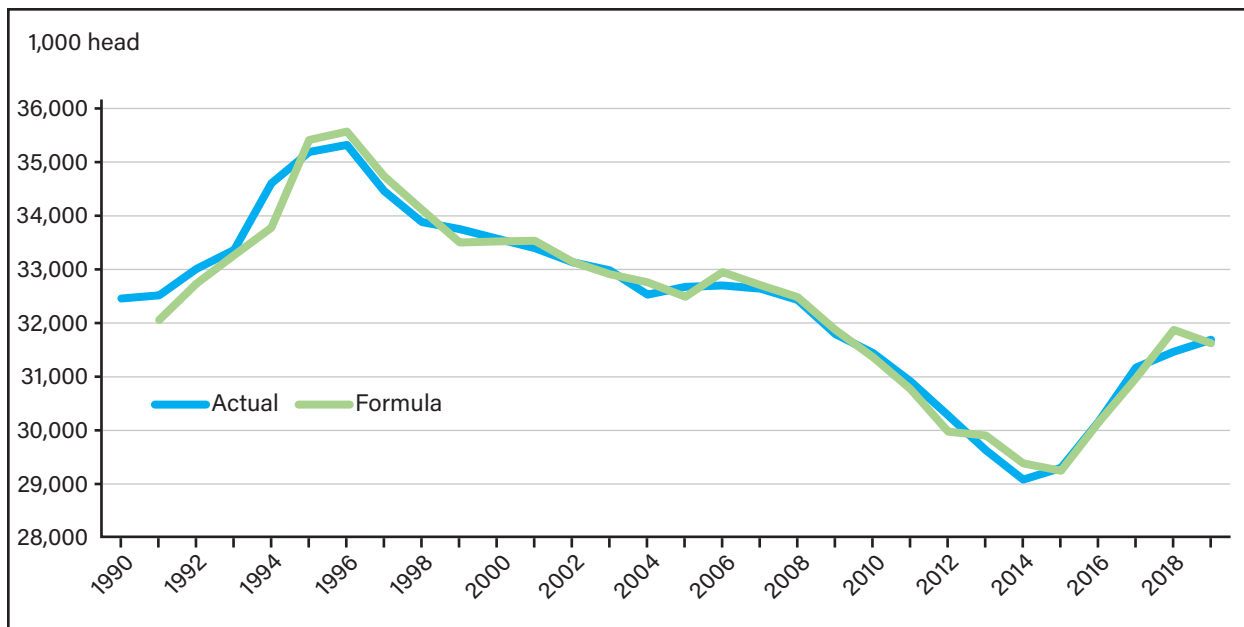
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B10
Calf crop
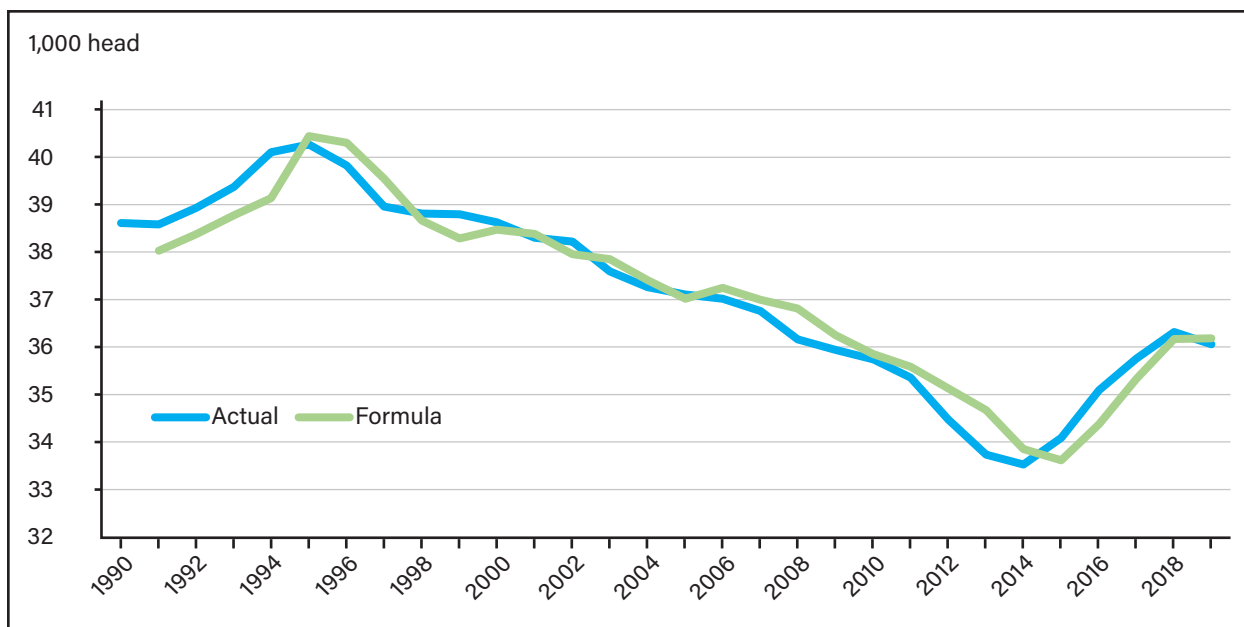
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B11
Calves under 500 pounds
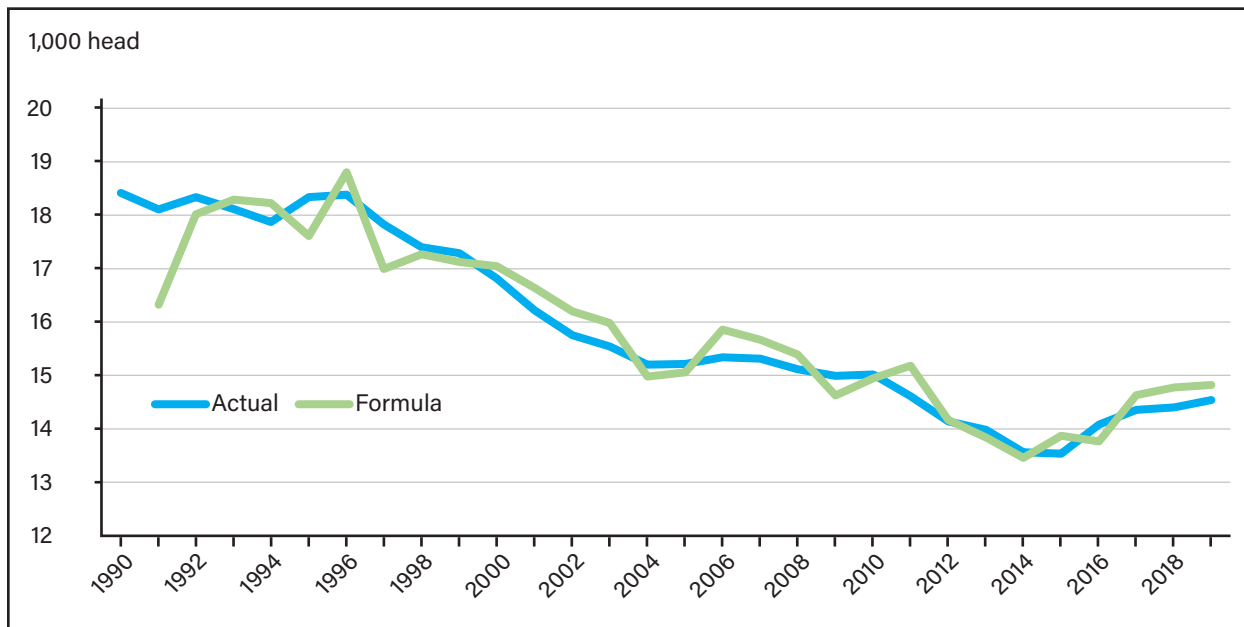
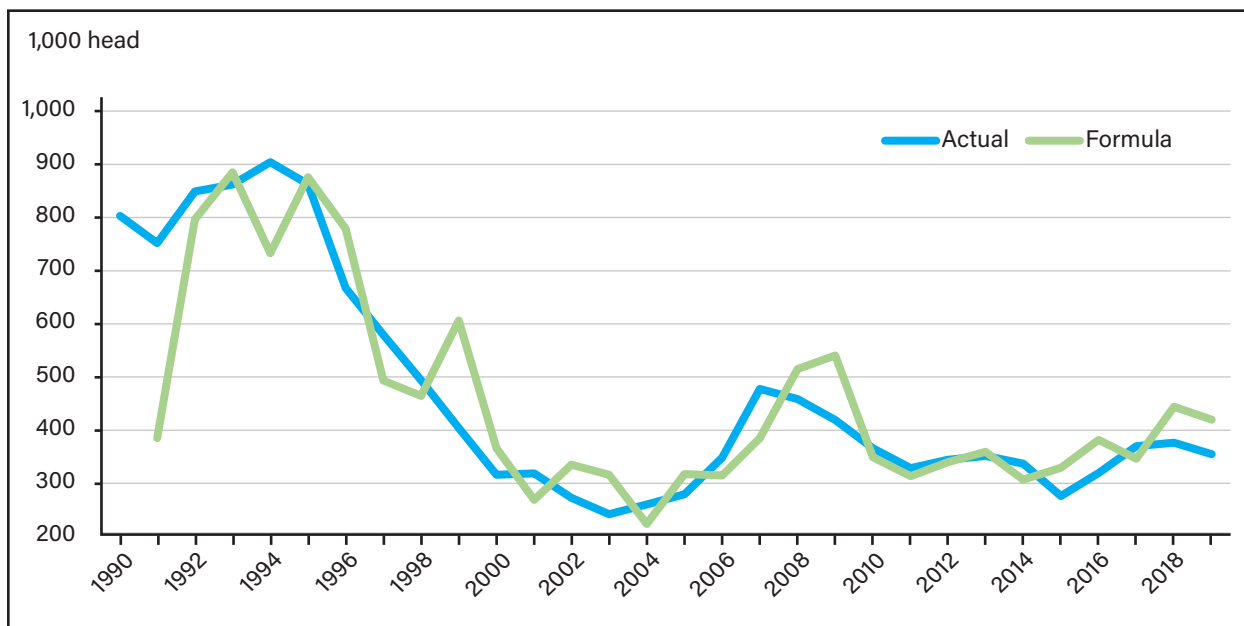Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B12
Steers over 500 pounds
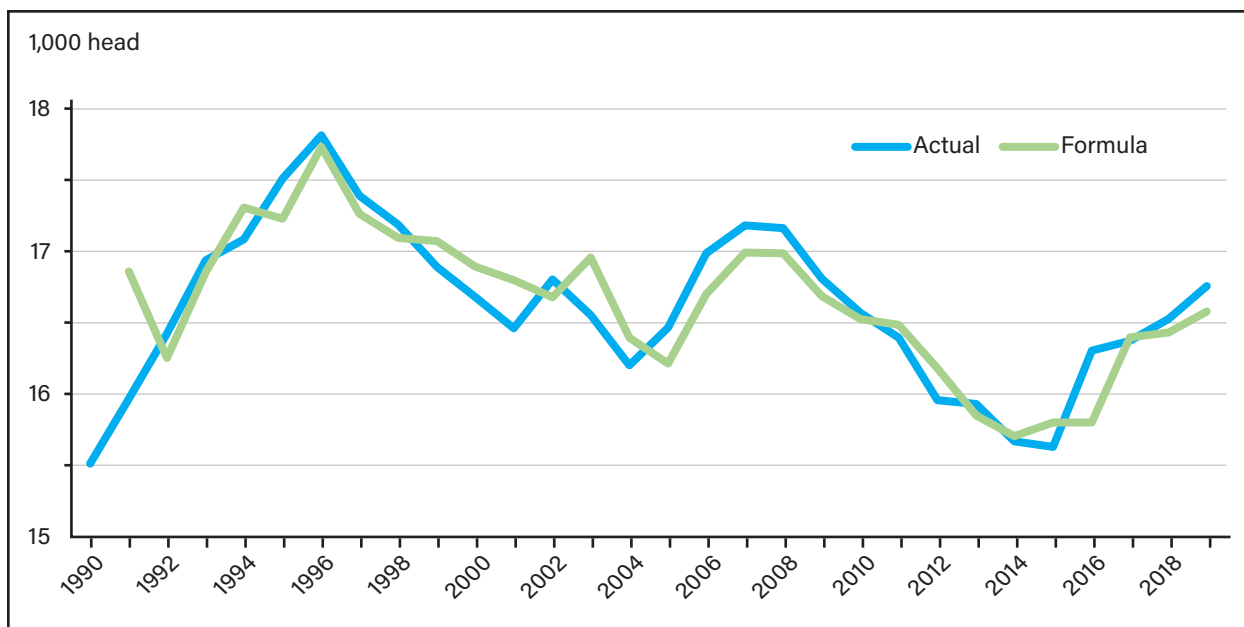
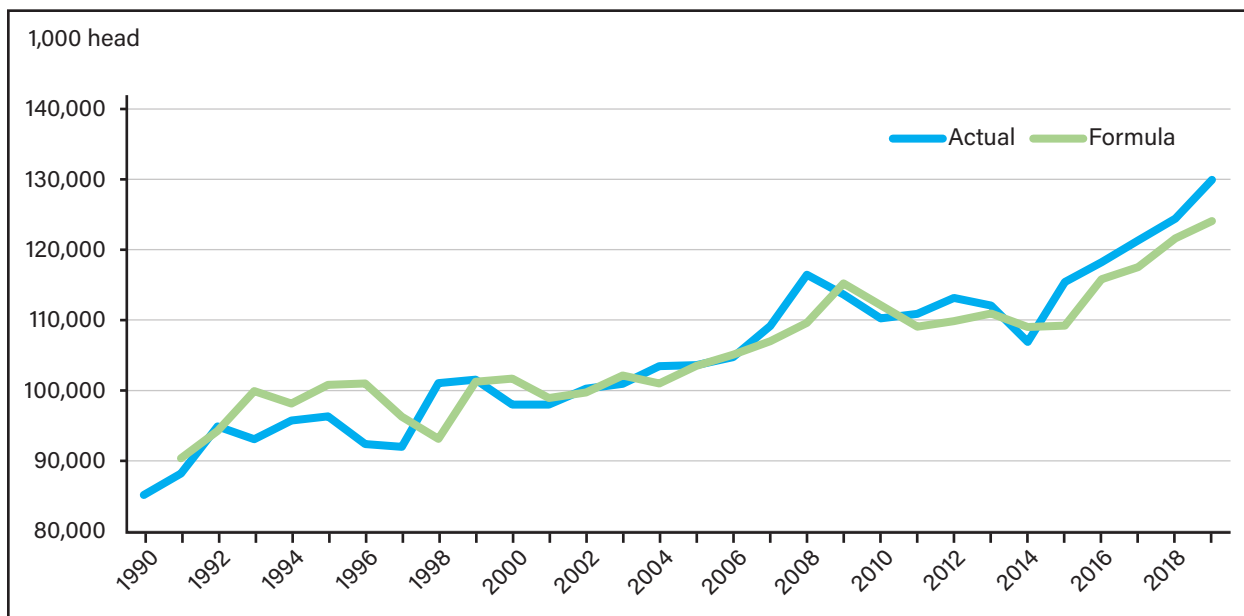Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B13
Other heifers over 500 pounds
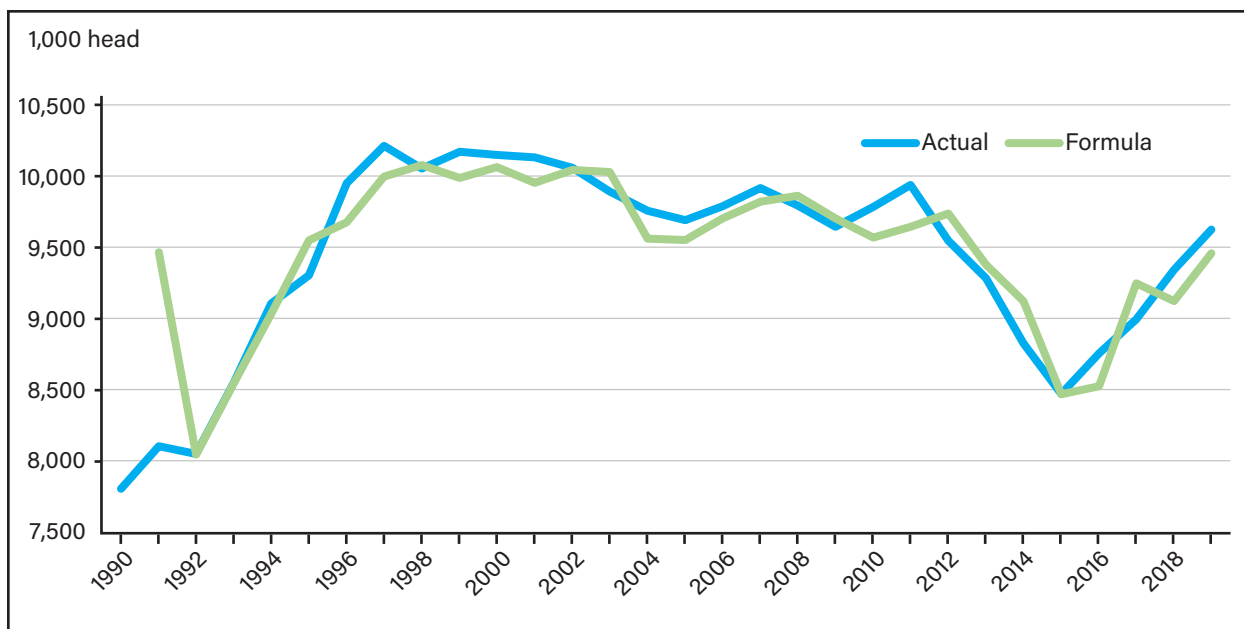
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B14
Beef heifers for breeding
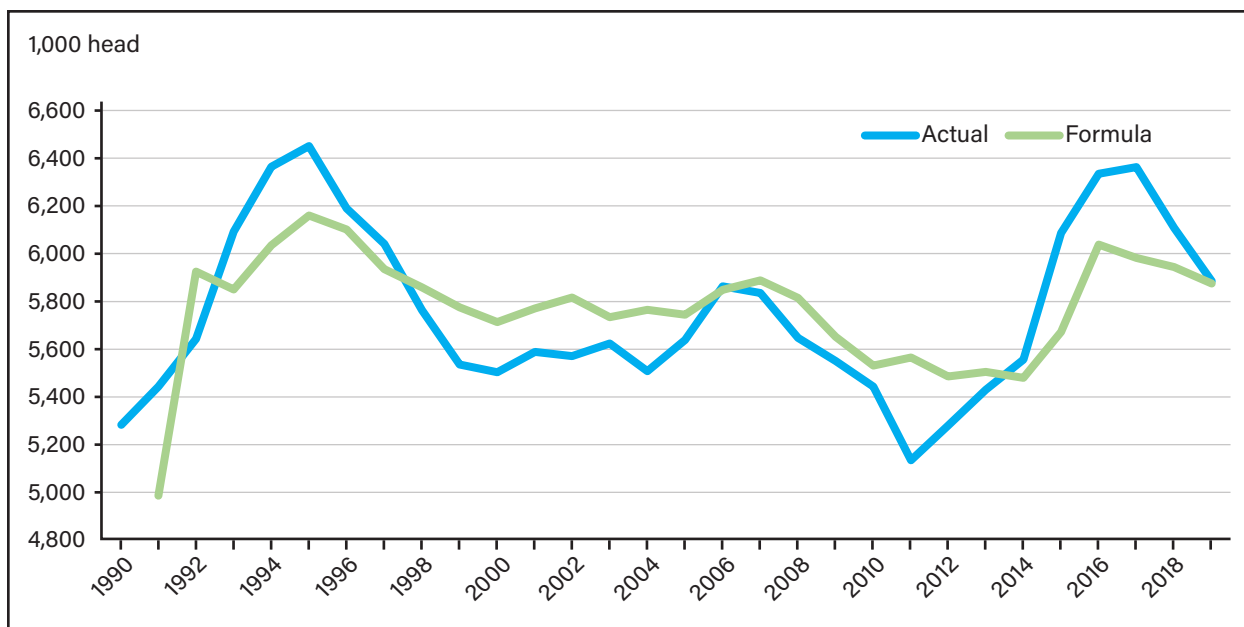
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B15
Bulls over 500 pounds
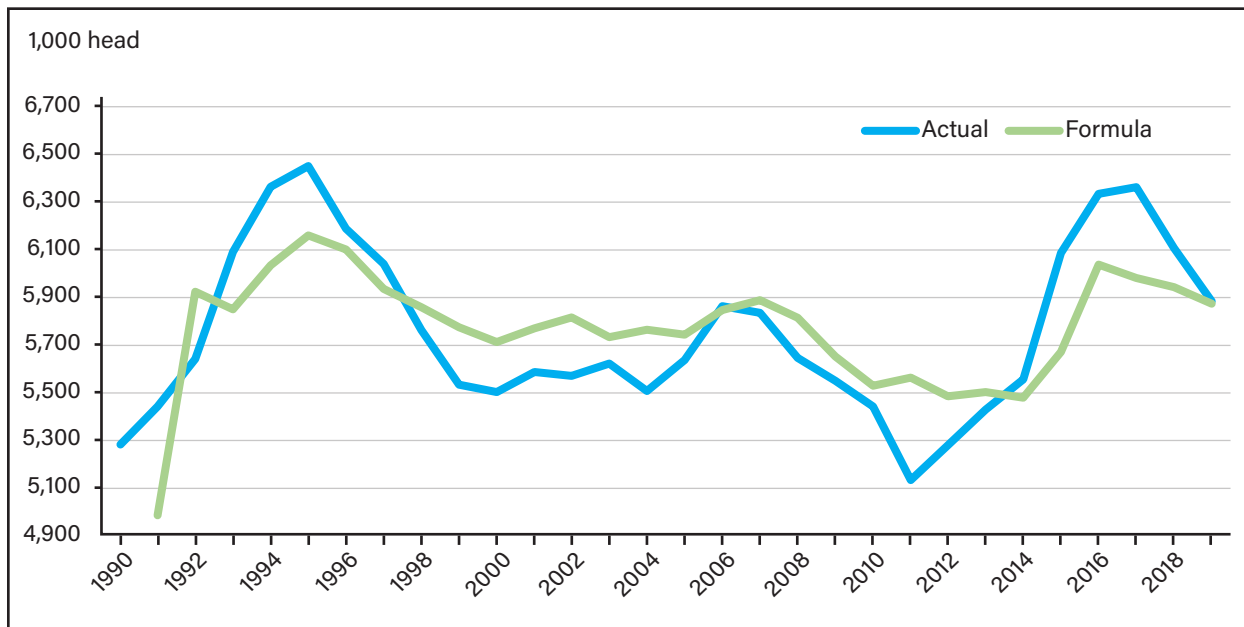
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B16
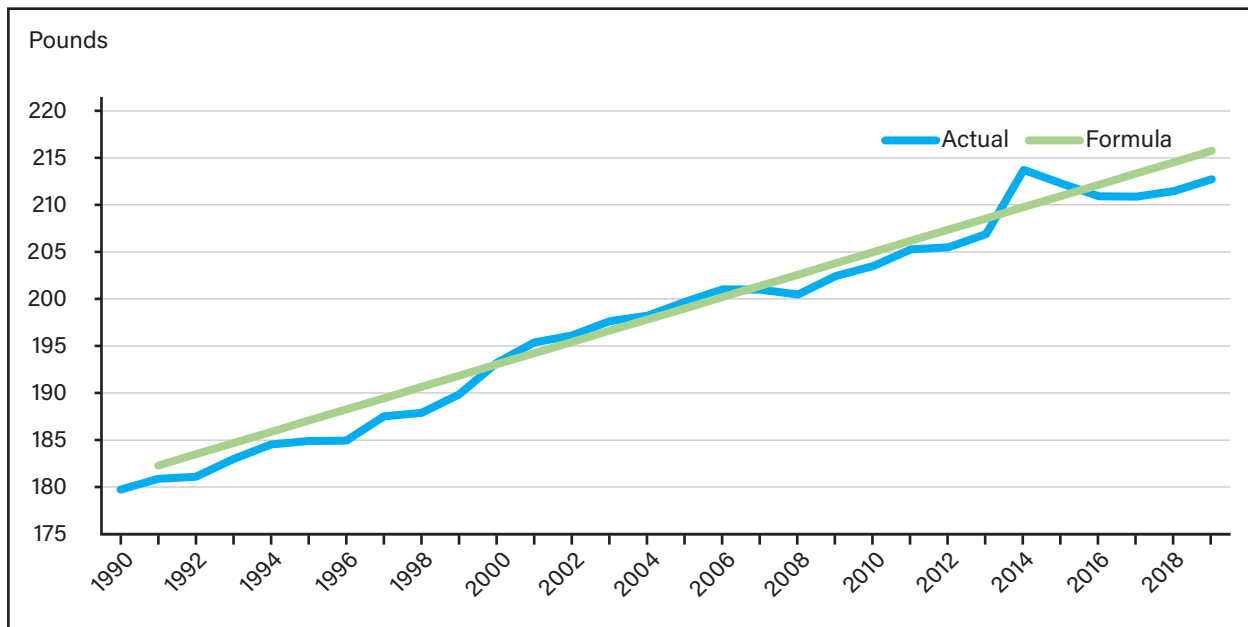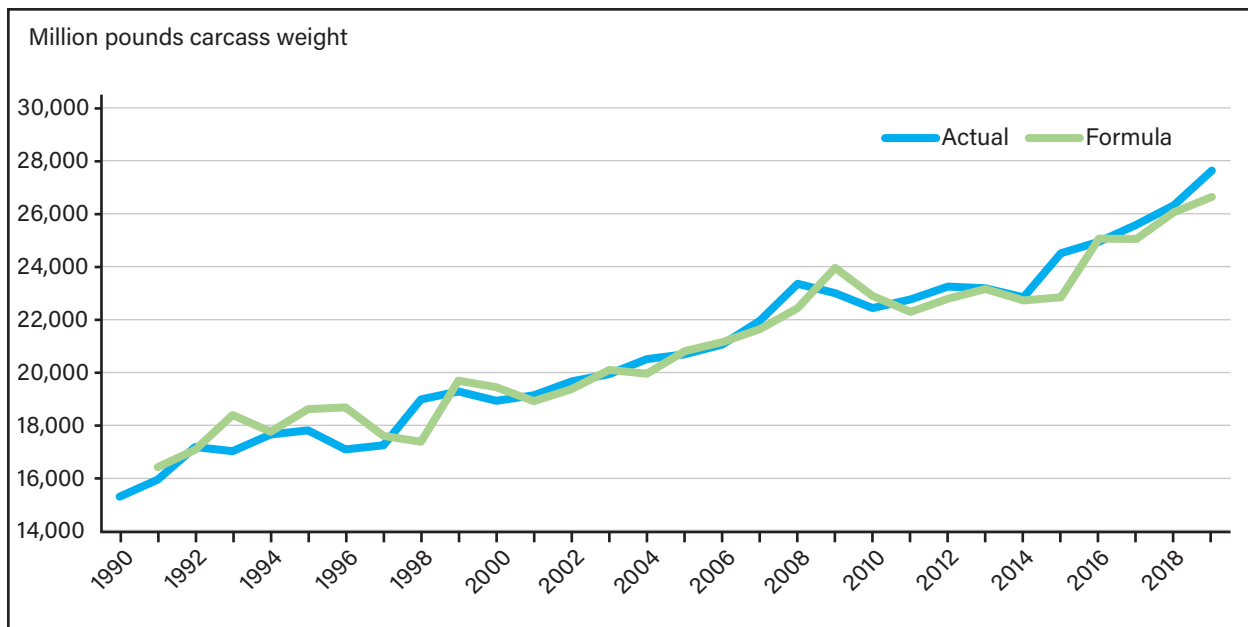**Federally inspected steer slaughter**
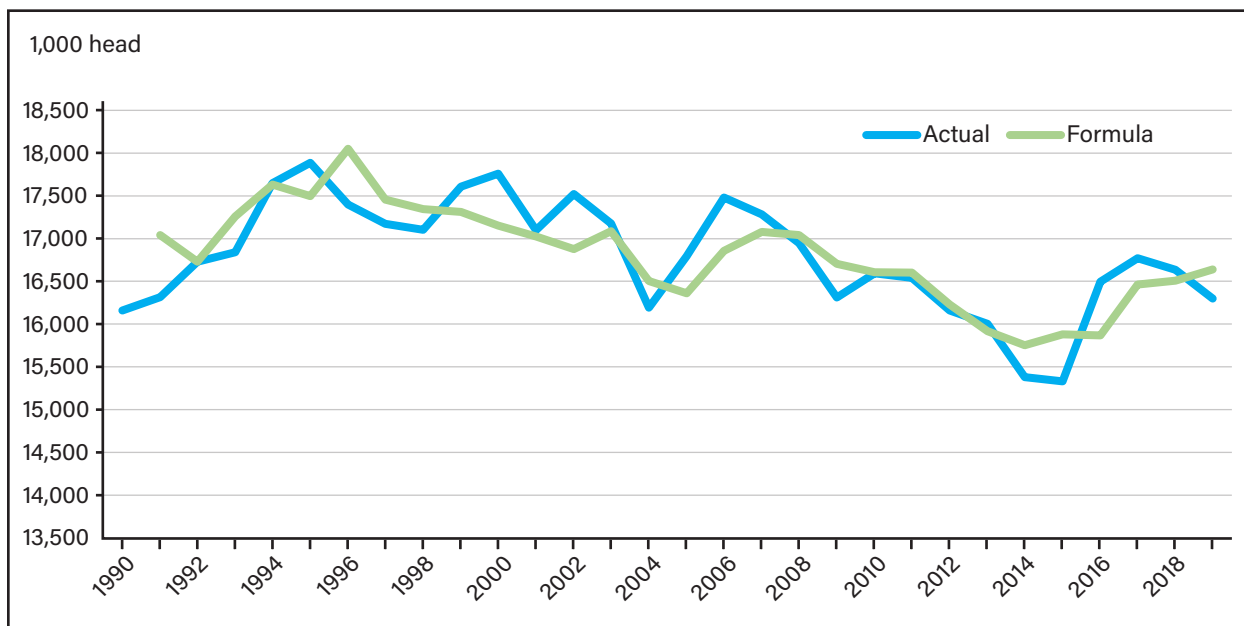
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B17
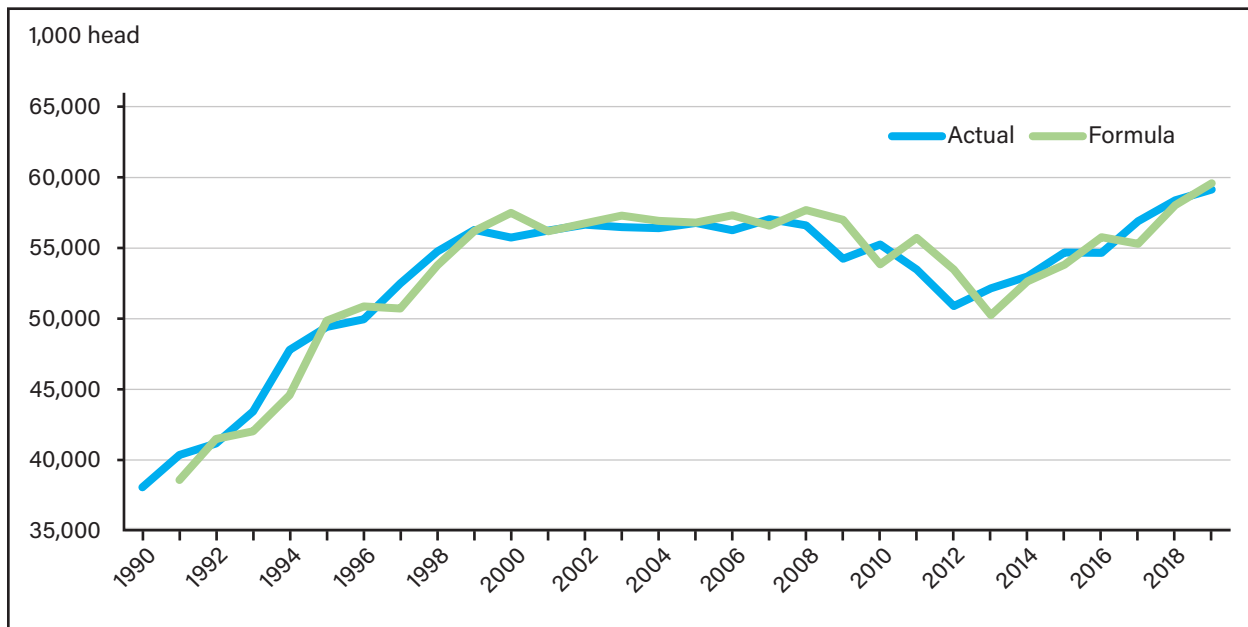**Federally inspected dairy cow slaughter**

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B18
Federally inspected beef cow slaughter
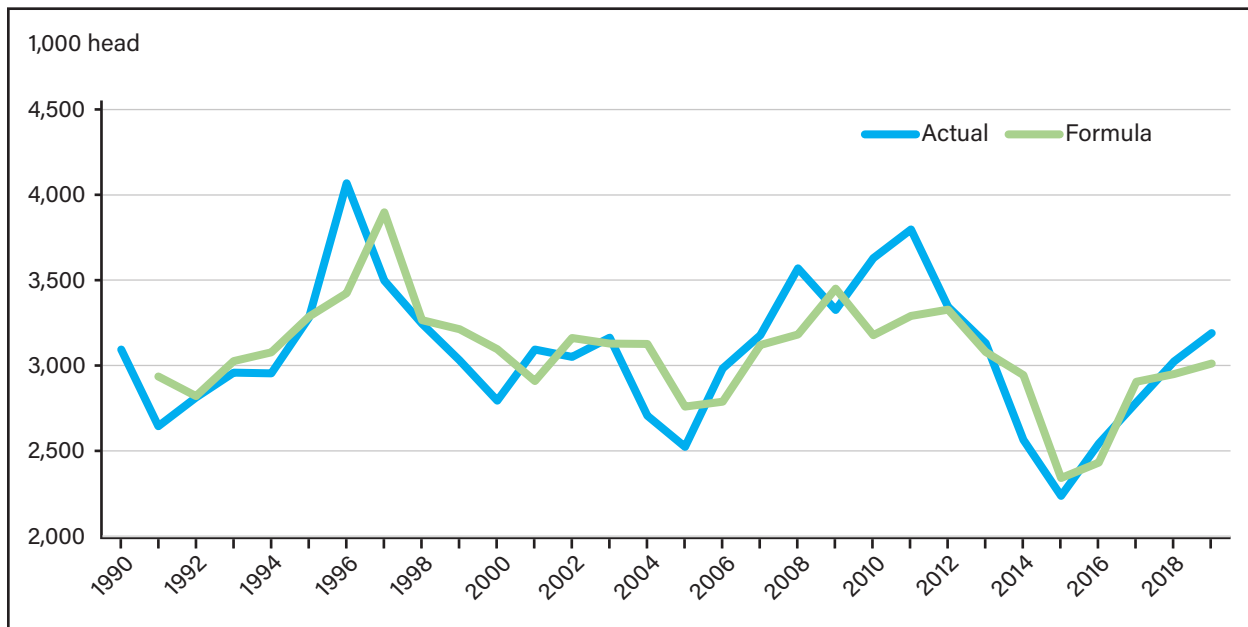
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B19
Federally inspected heifer slaughter
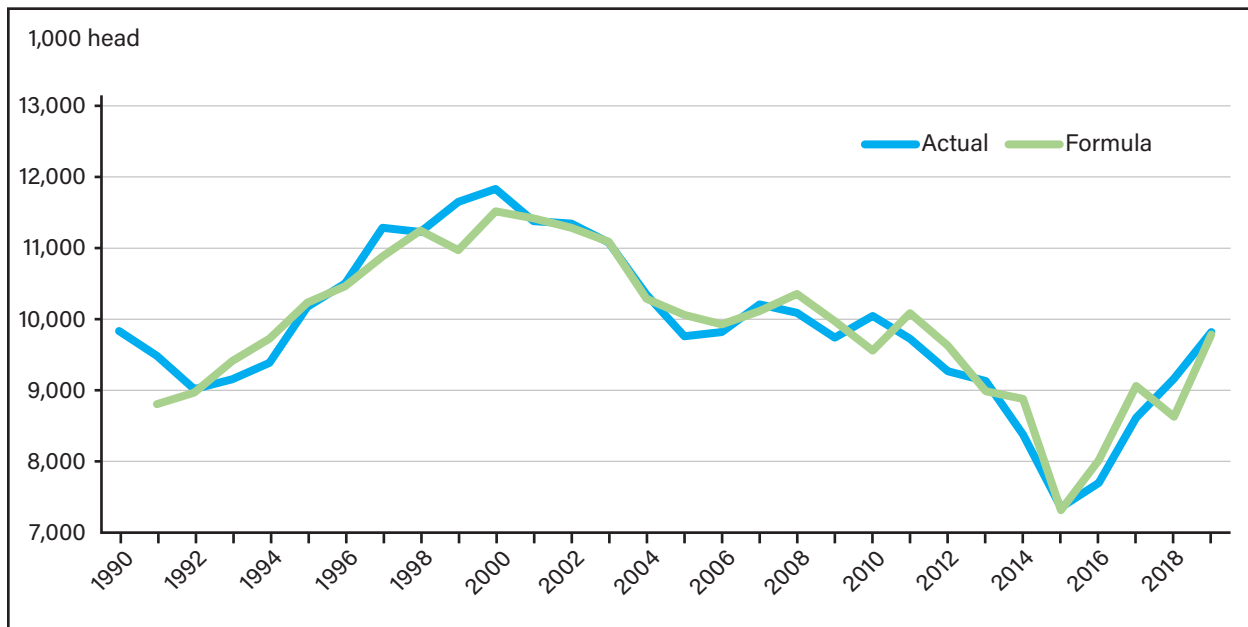
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B20
Commercial cattle slaughter
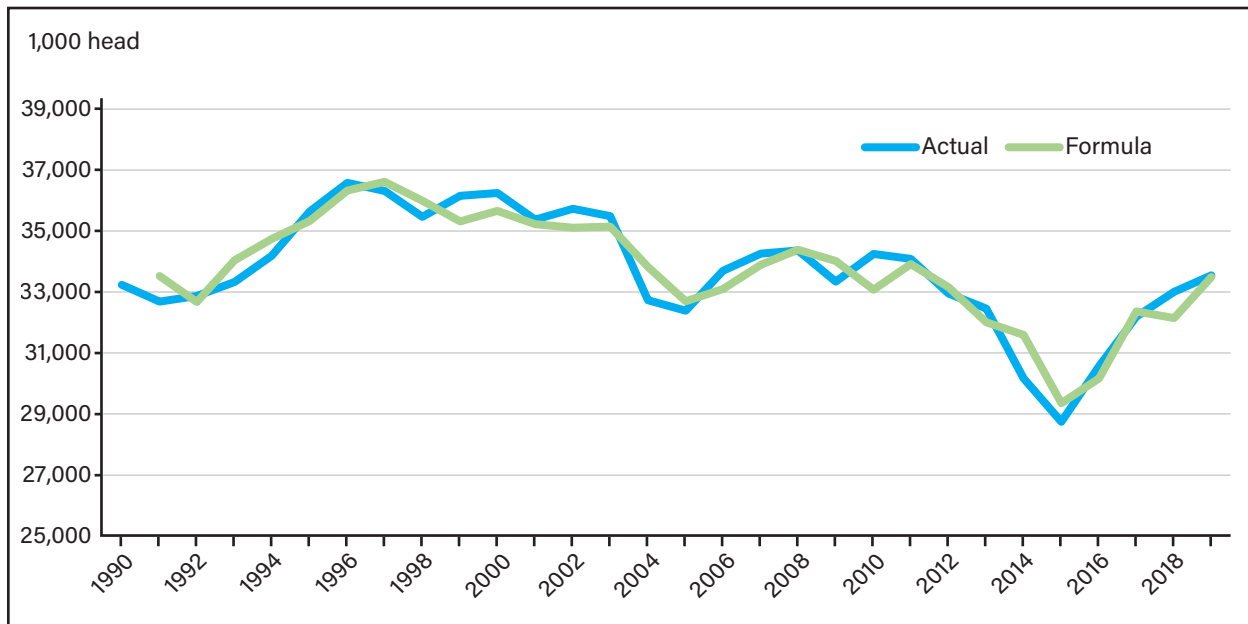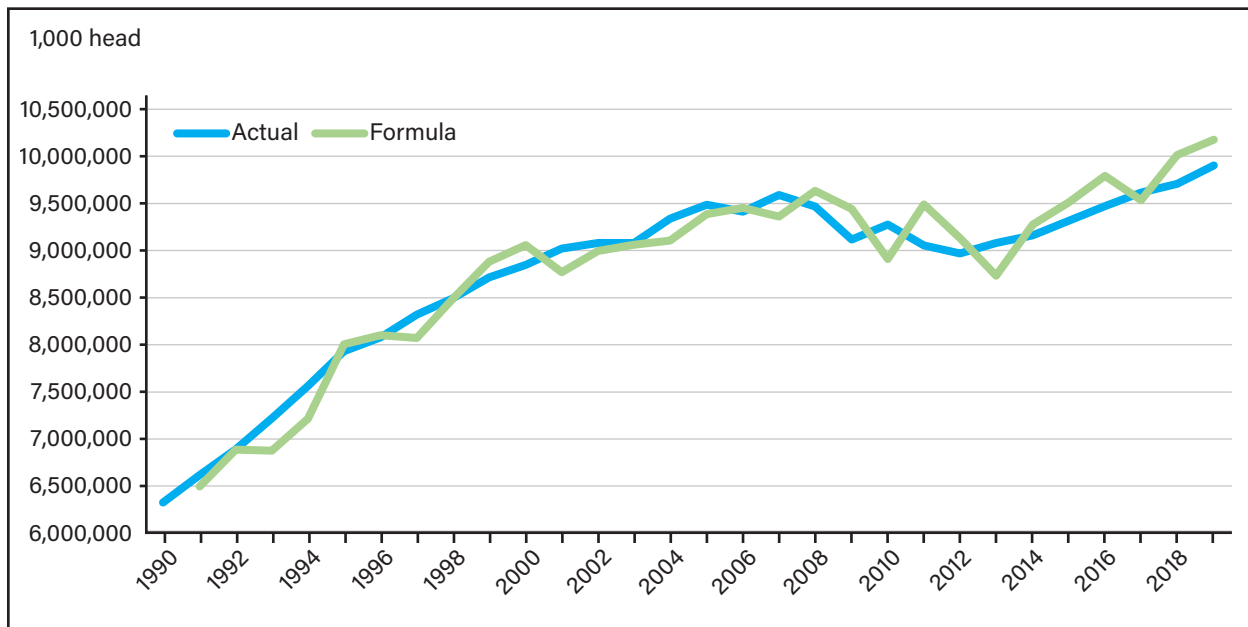

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B21
Commercial cattle slaughter weights
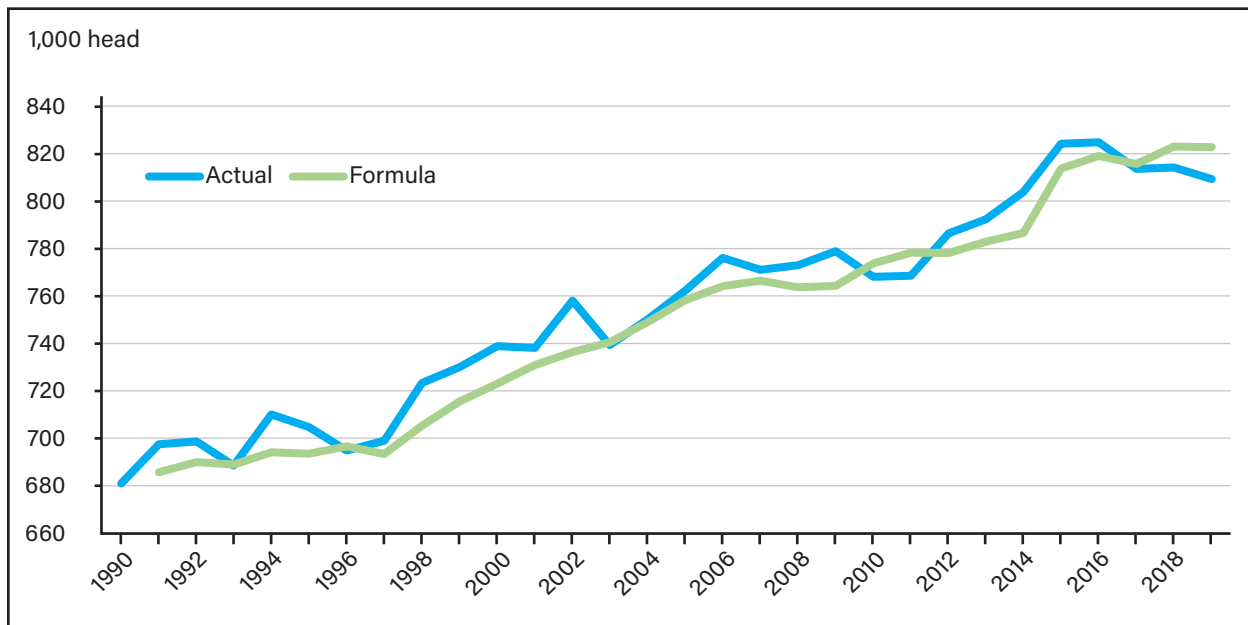
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
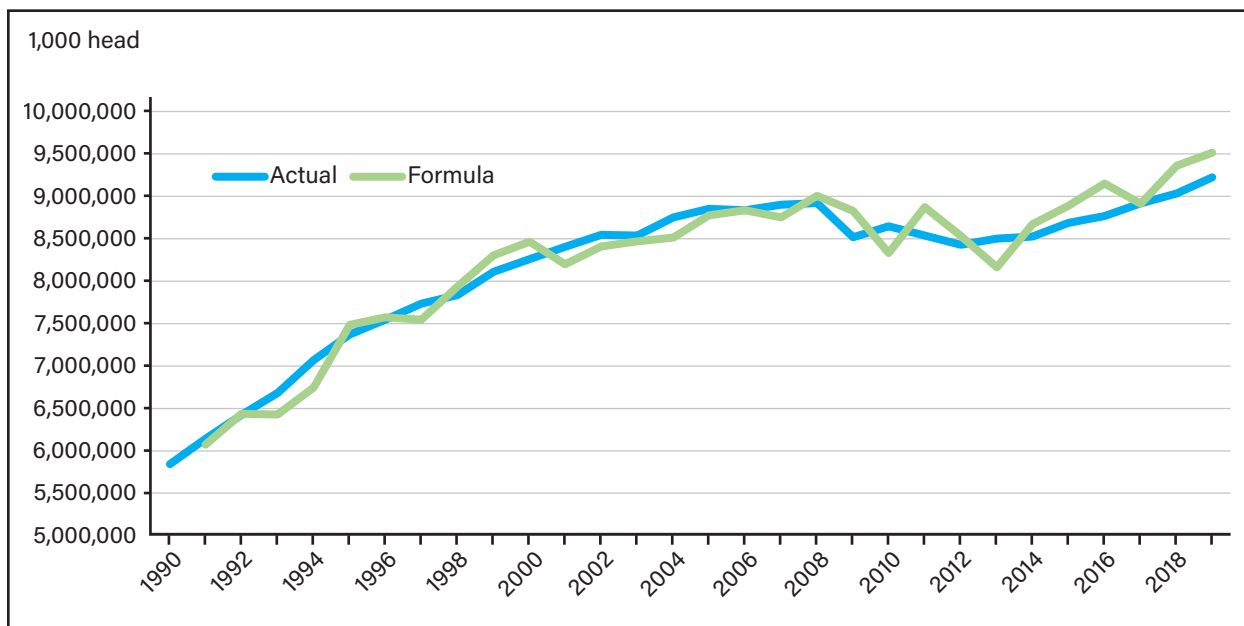
Figure B22
Commercial beef production
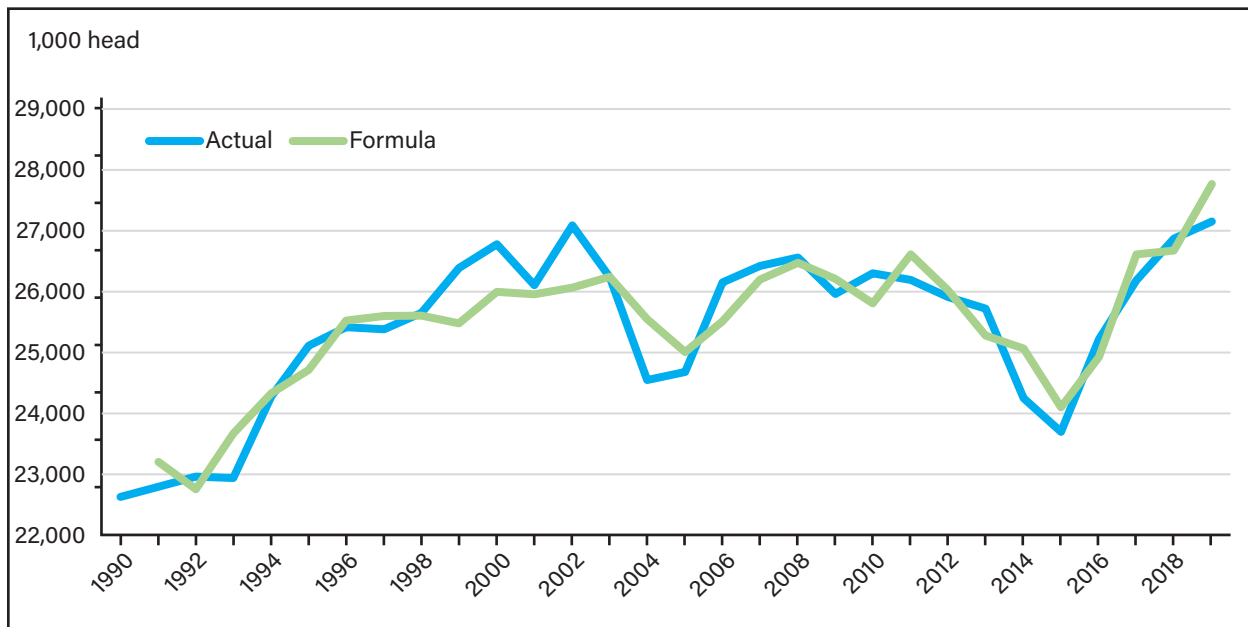
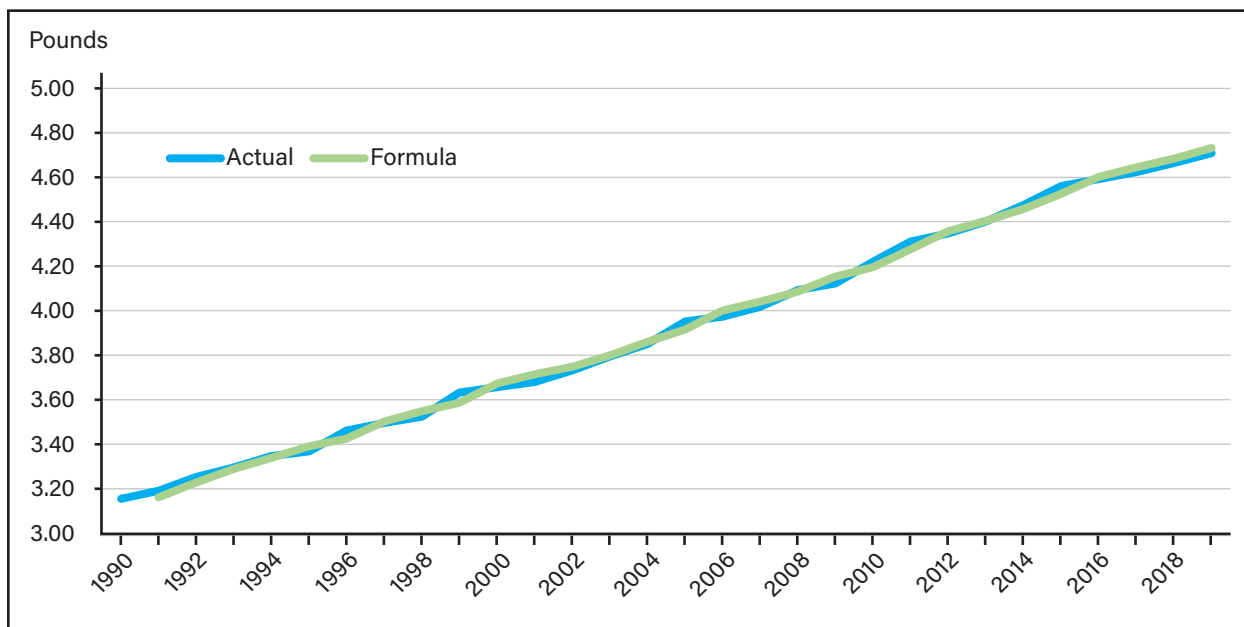Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B23
Sows farrowing

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
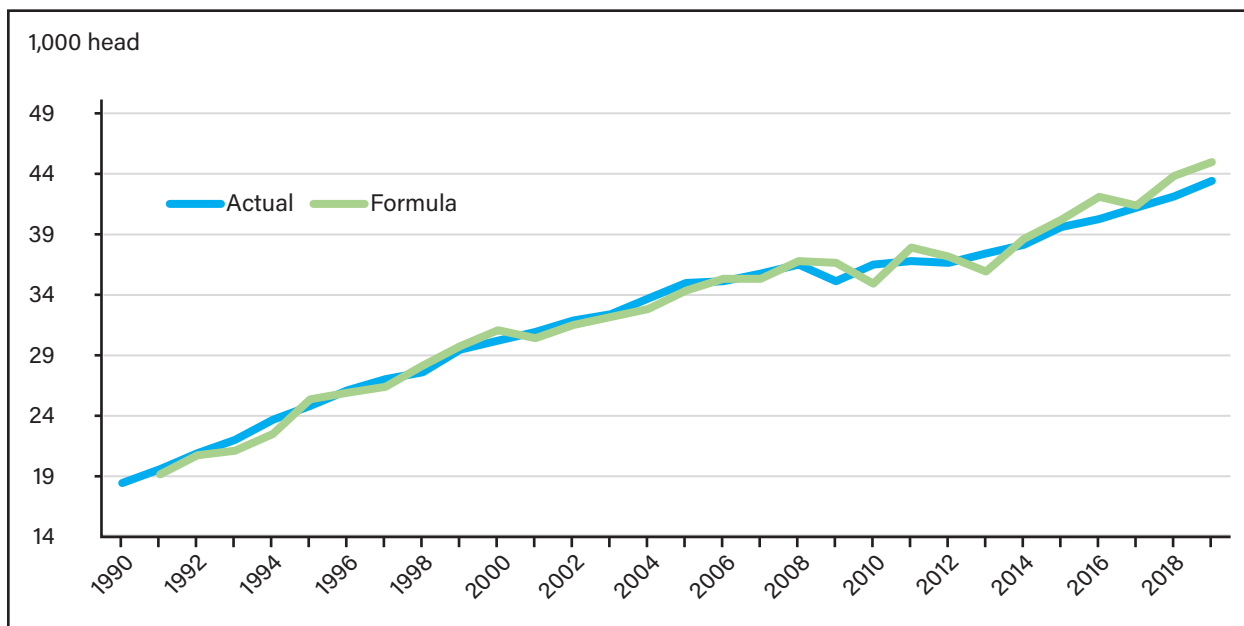USDA, Economic Research Service

Figure B24
Pig crop

1,000 head

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B25
Pigs per litter

1,000 head

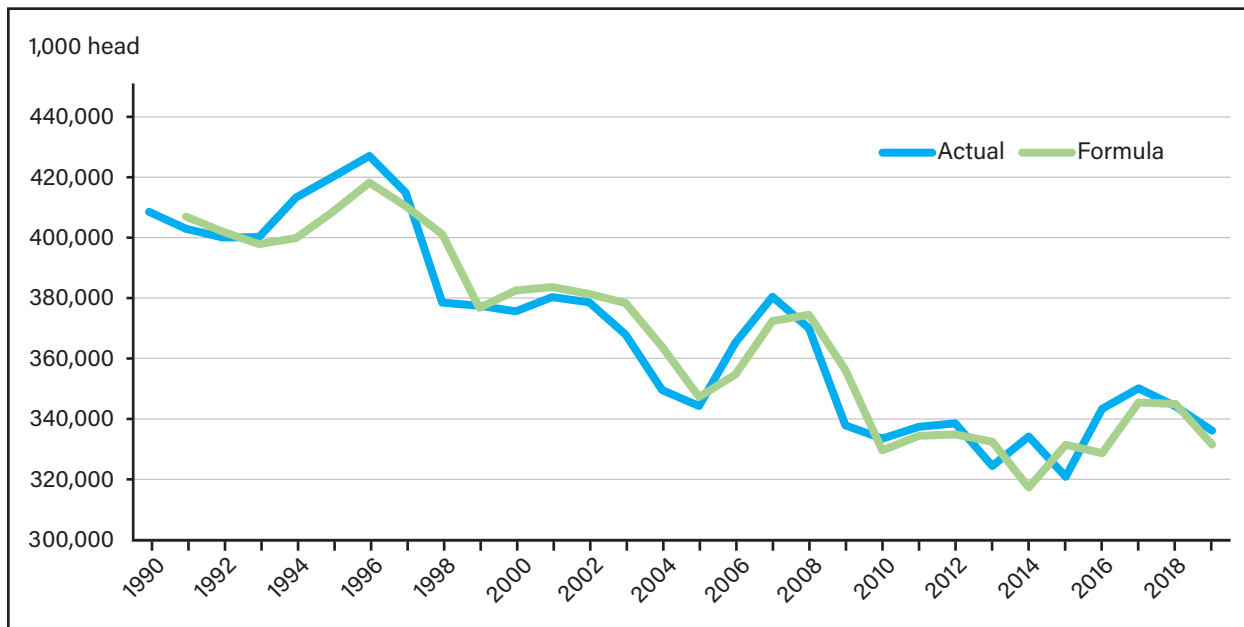

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B26
Federally inspected barrow and gilt slaughter

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B27
Federally inspected sow slaughter

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B28
Federally inspected boar slaughter

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B29
Commercial hog slaughter
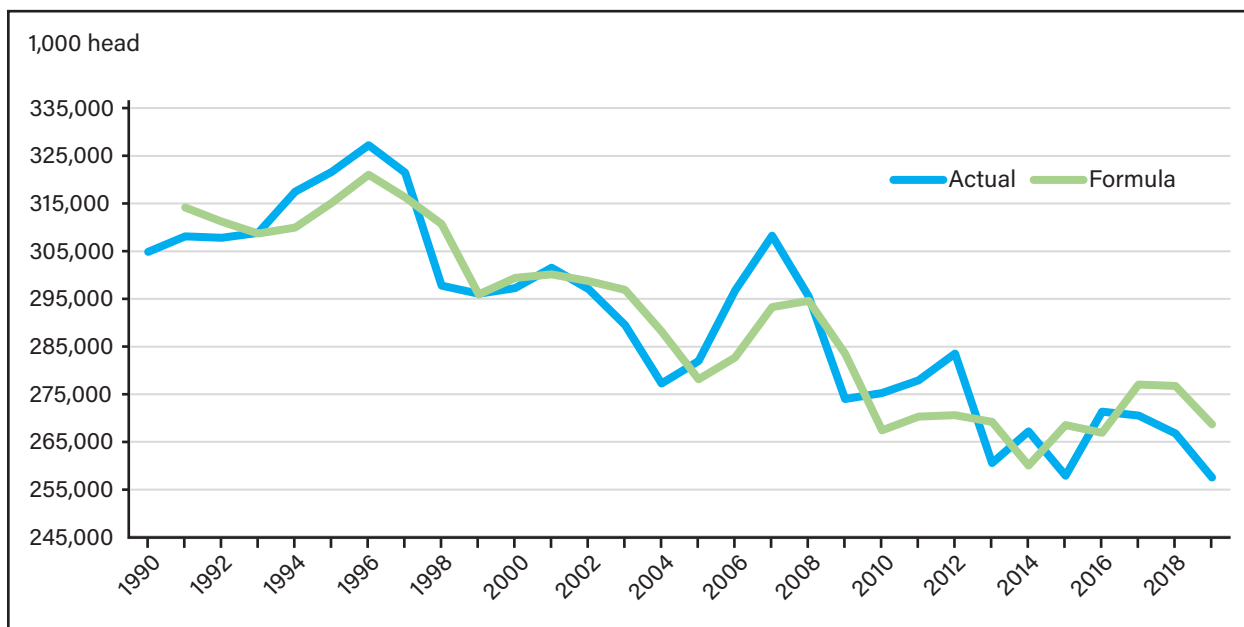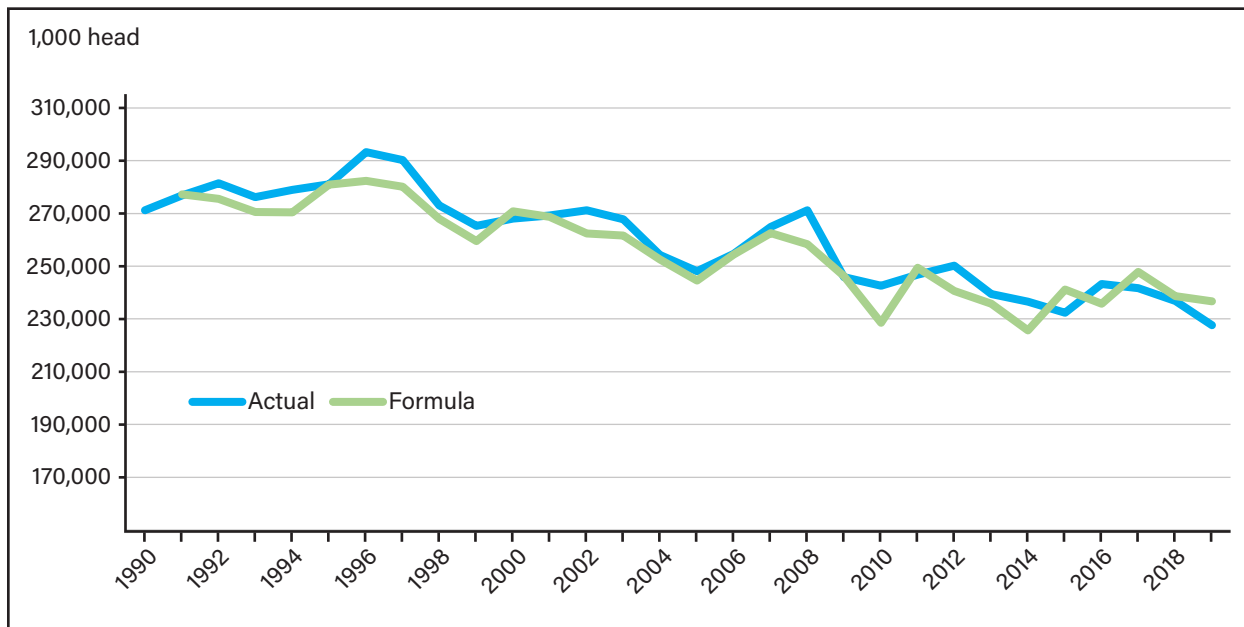

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B30
Hog carcass weight

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
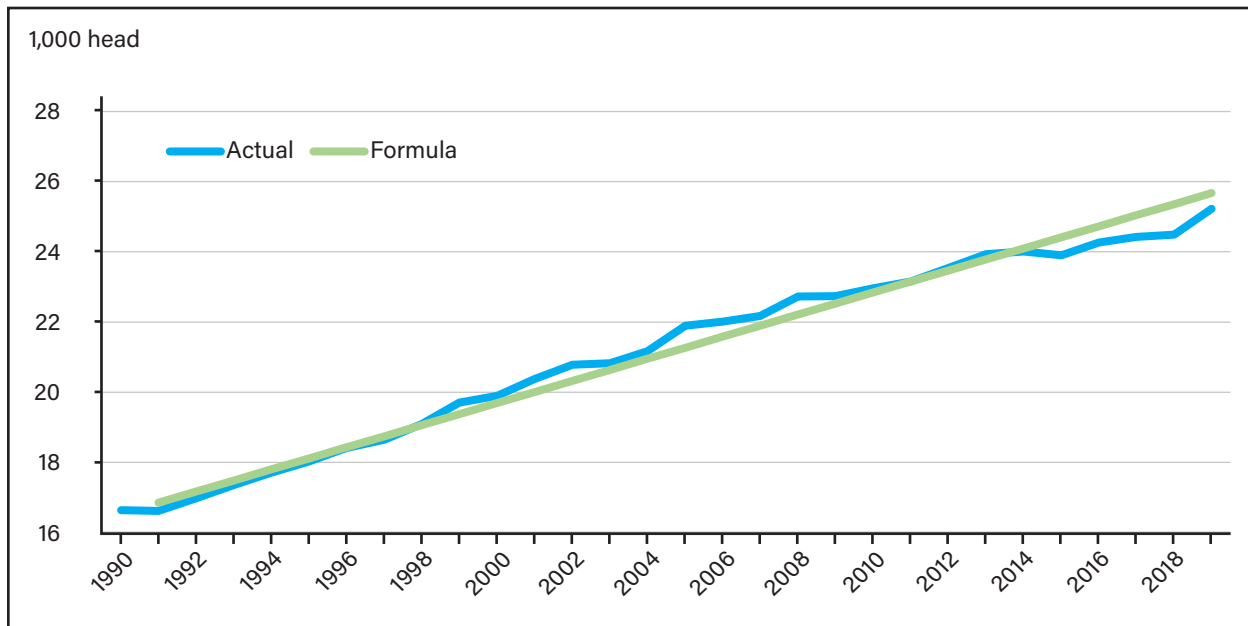
Figure B31
Commercial pork production

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B32
Broiler hatching flock
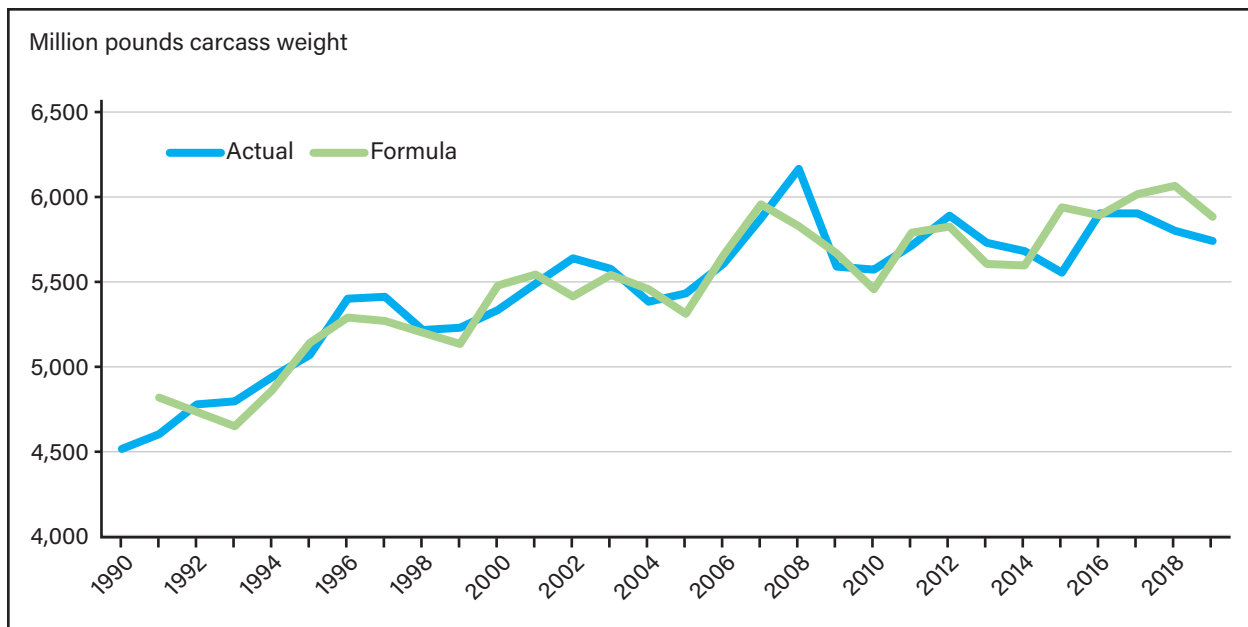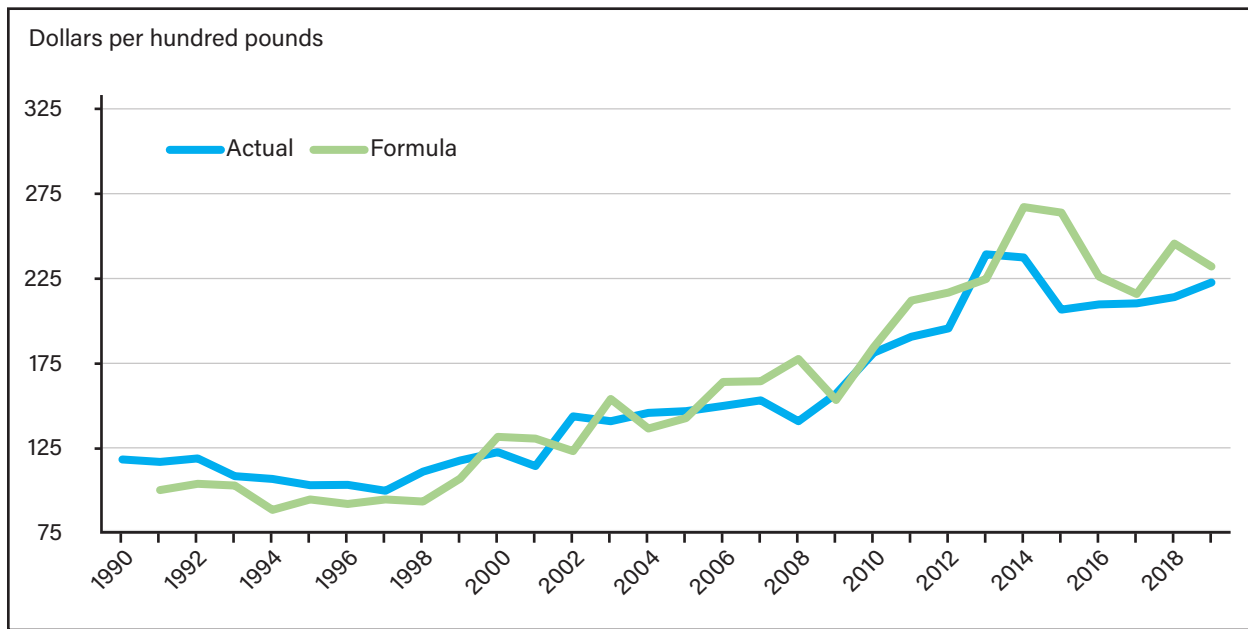

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B33
Broiler chicks hatched

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
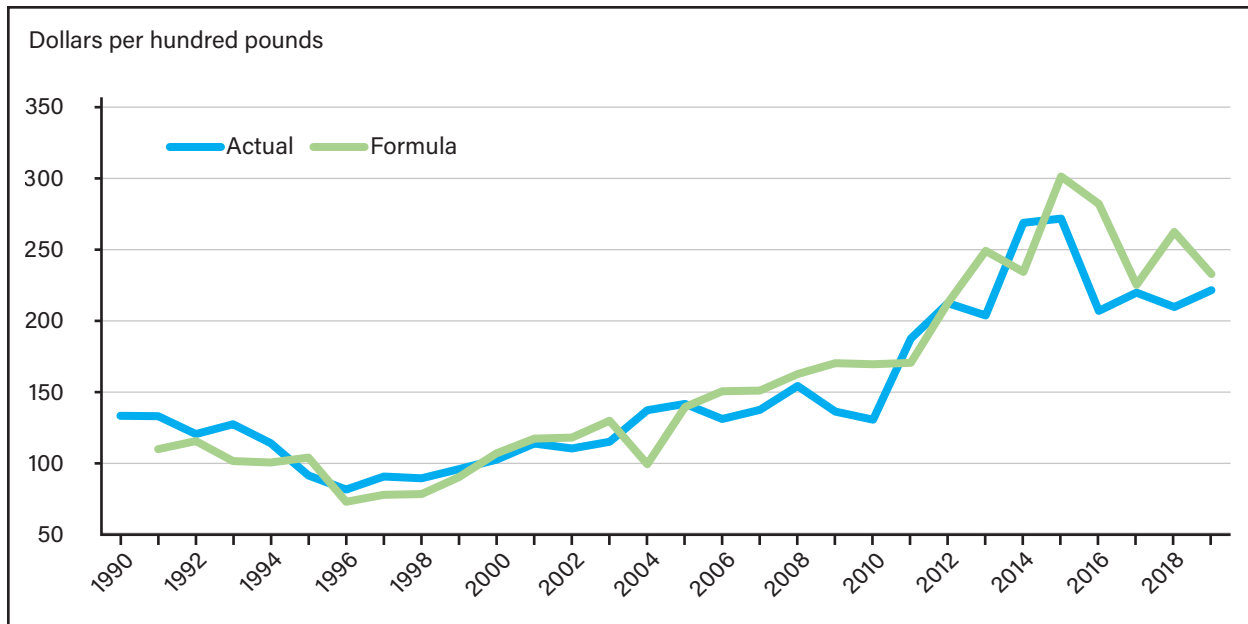USDA, Economic Research Service

Figure B34
Broilers slaughtered

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B35
Broiler weights per bird ready-to-cook basis

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Structure of the USDA Livestock and Poultry Baseline Model, TB-1956
USDA, Economic Research Service

Figure B36
Commercial broiler production

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
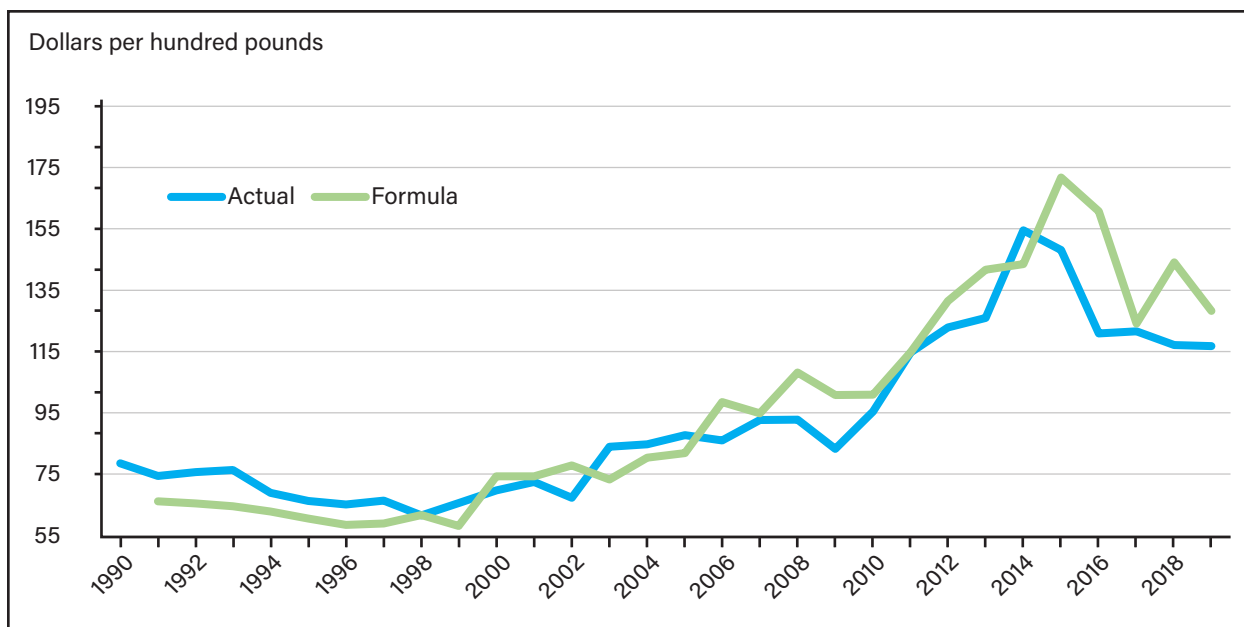
Figure B37
Turkey eggs in incubators

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B38
Turkey poults placed

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B39
Total turkey slaughter

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B40
Turkey weights per bird ready-to-cook basis

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B41
Commercial turkey production

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure B42
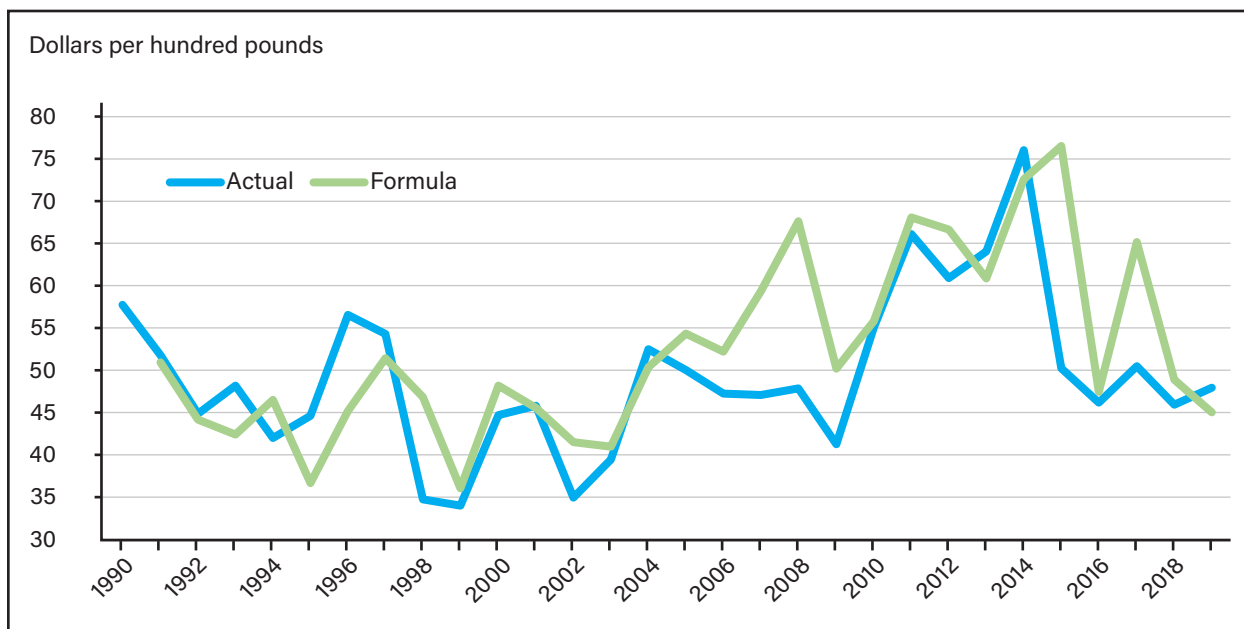**Choice beef cutout**

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.
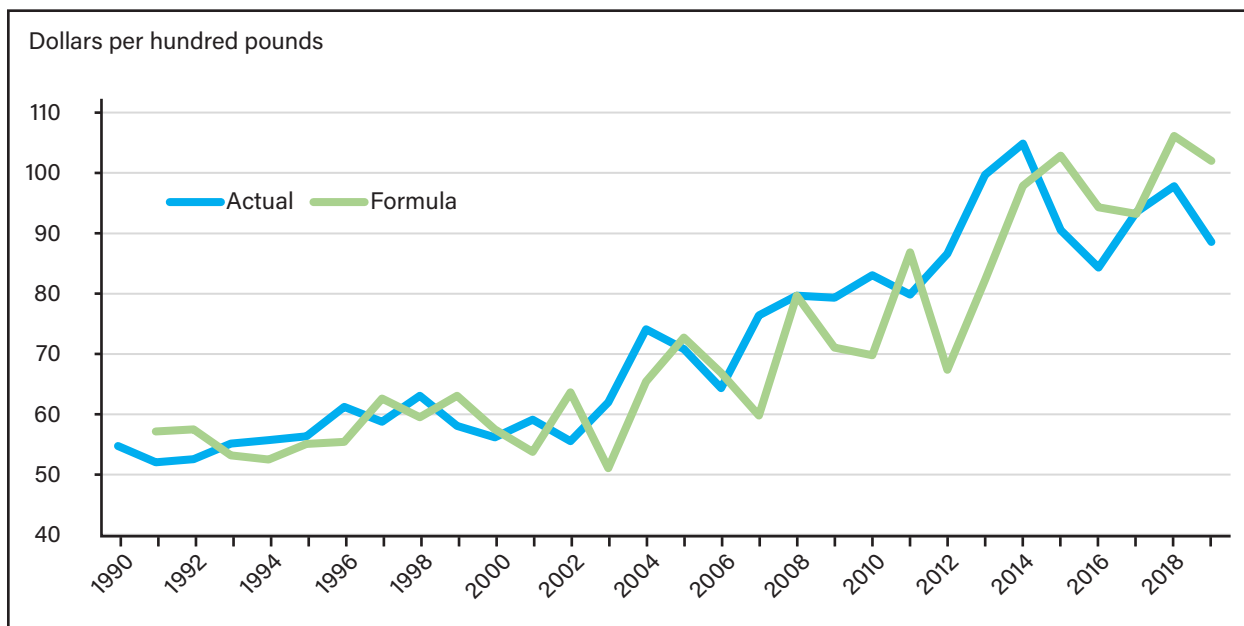
Figure B43
Fresh 90-percent lean trimmings

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B44
Steer price

Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B45
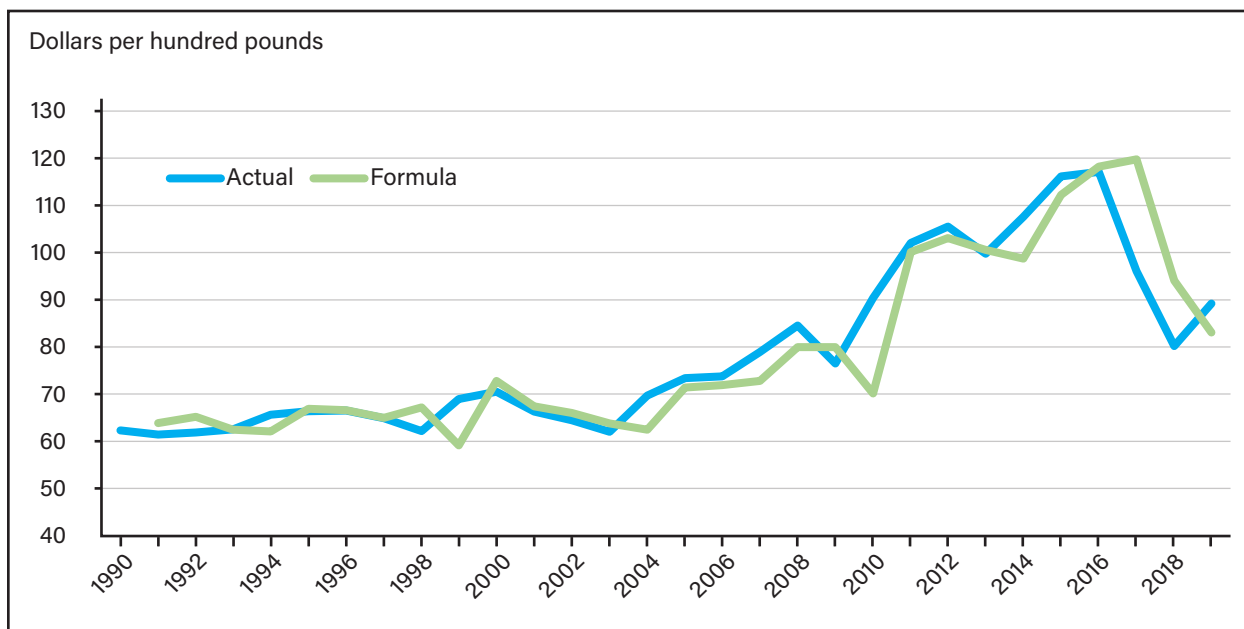**Cull cow price**
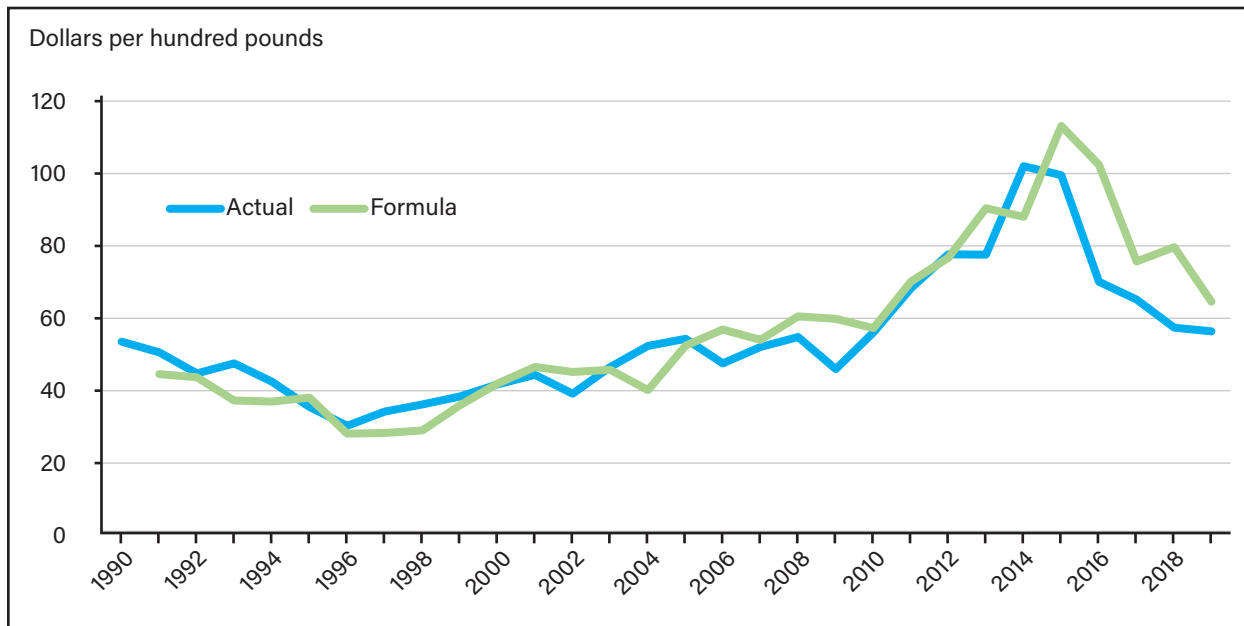
Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B46
Feeder steer price
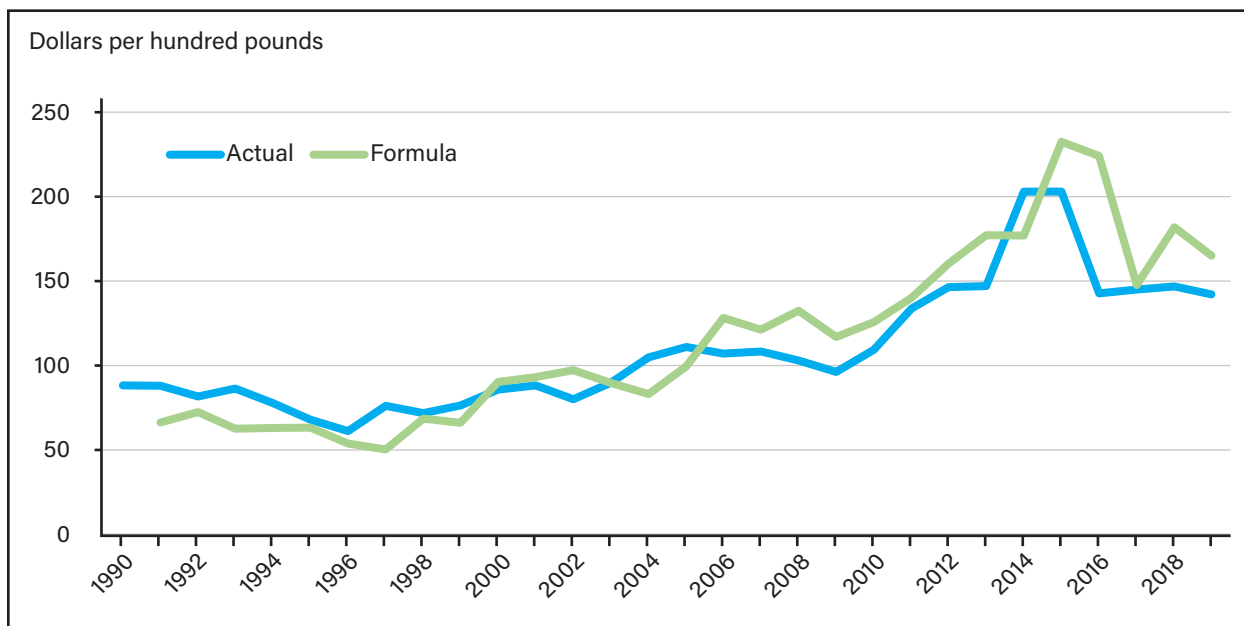
Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B47
Barrow and gilt price

Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B48
Wholesale broiler price

Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.

Figure B49
Wholesale turkey price

Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Appendix C: Additional Model Analysis

Many equations in the Domestic Baseline Livestock Model use lagged values. The value of a variable in a given year depends on its own or other variables in the previous year and in a few cases, 2 previous years. The "formula" values in appendix B use those lagged values to make a year's forecasts. When USDA personnel make projections for the baseline, they use 1 year's forecasts to make the following year's forecasts. For example, in the 2021 baseline report, USDA personnel could use 2020 data to project 2021 results. The 2021 projections were used to make the 2022 forecasts, and so on.

This appendix shows projections for the years 1991–2019 for 8 of the variables in the DBLM. These projections use 1991's projections to calculate 1992's values, 1992's projections to generate 1993's values, and so on. The projections/simulations here are more like those generated in the baseline process.

The 1991 projections in this appendix are considered the 1991 forecast given 1990 data and a 1-step-ahead forecast. The 1992 projection is a 2-step-ahead forecast. The 2019 projection would be a 29-step-ahead forecast. The 29-year-ahead forecast would likely fit the actual data worse than a 1-step-ahead forecast because of the longer timeline.

The eight variables shown here are total meat production for each of the species and one of each species' prices. The supplies of beef, pork, chicken, and turkey are all functions of feed costs. Lowering feed costs for all four species will increase their supplies; higher supplies will lead to lower prices. This appendix also shows the results of a simulation where the prices of corn, hay, and soymeal were 25 percent lower each year from 1991–2019 inclusive. This low-feed-cost simulation demonstrates how meat supplies and prices respond to feed costs.
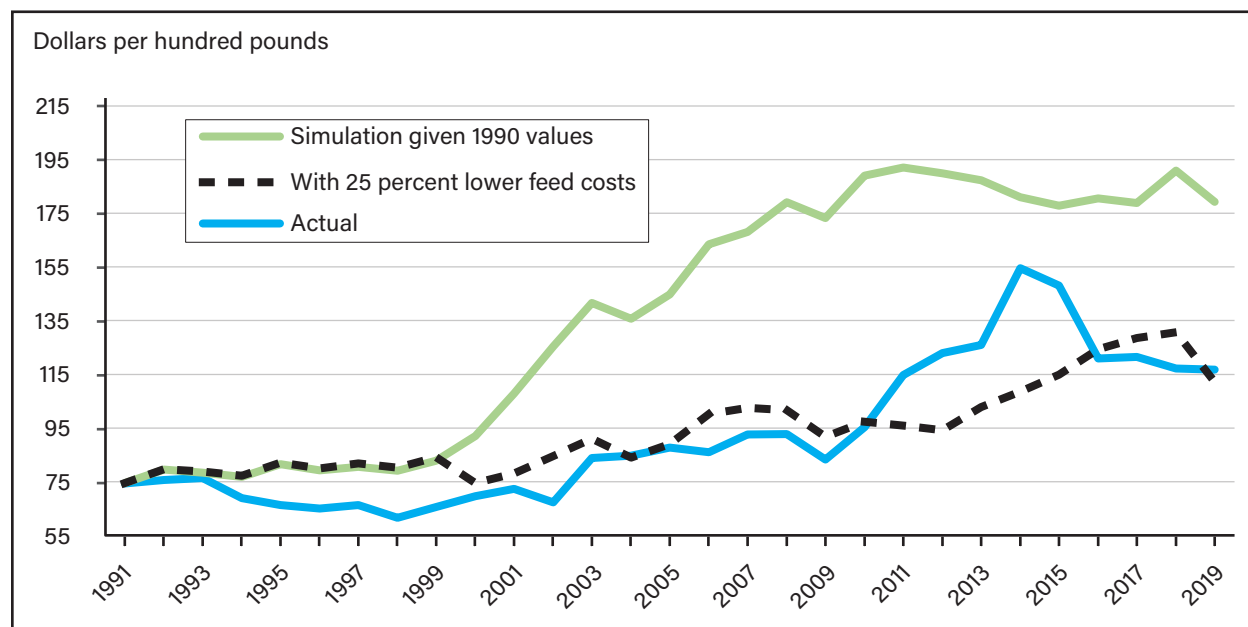
Cattle/Beef Projections

Figure C1
Commercial beef production
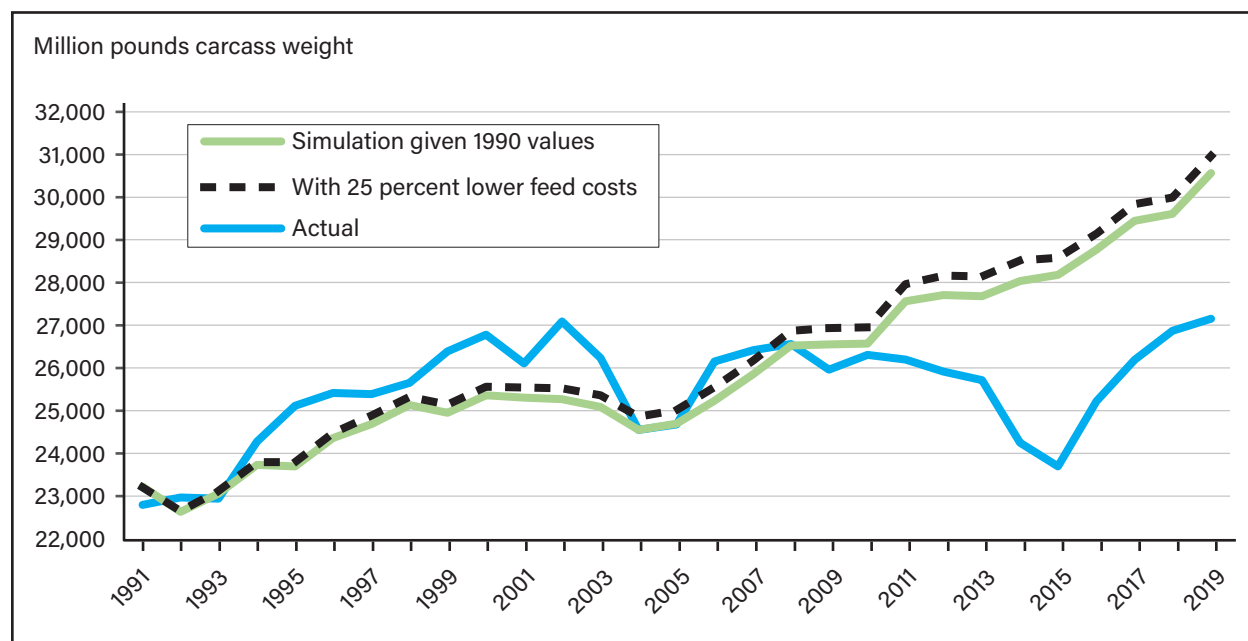
Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
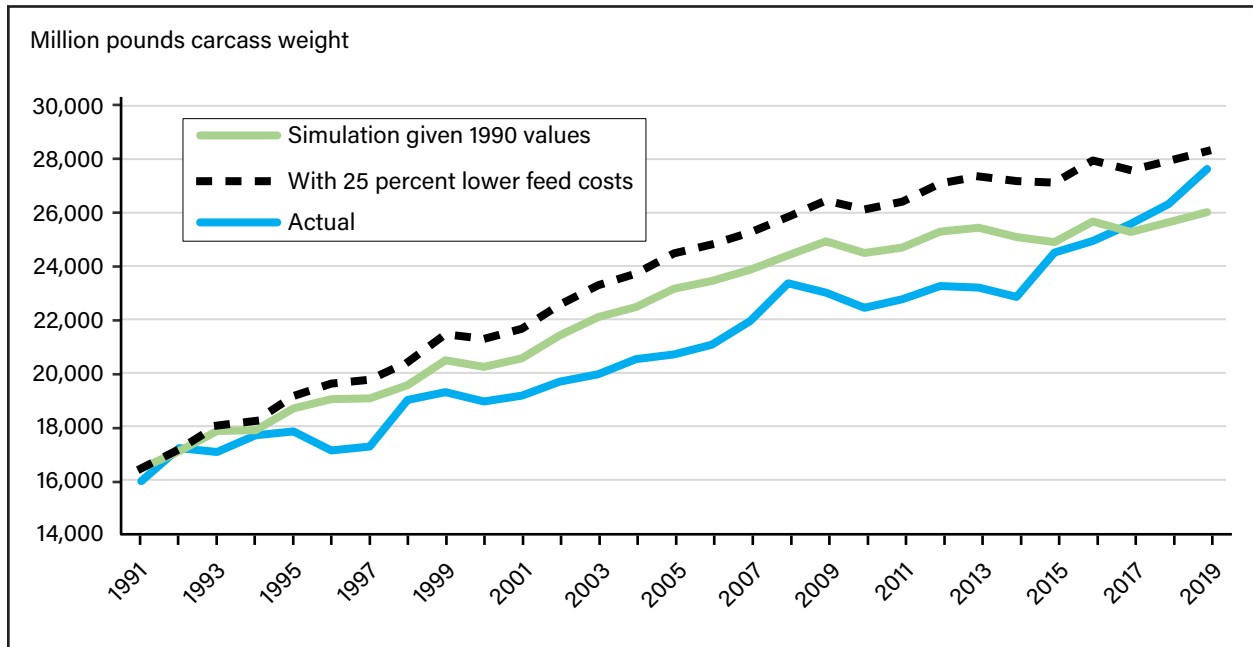
Figure C2
Steer price

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

The multi-step ahead forecasts are generally more stable than the actual data. Note also the difference between the lower feed costs and multi-step forecasts widens for total production and prices as the years progress. This widening reflects the dynamics in the supply response: The lagged quantities and prices in the cattle supply equations make cattle and beef supply react slowly to changes in market conditions. The simulated beef production in 2019 is 2 percent higher with lower feed costs; the steer price is 5 percent lower.
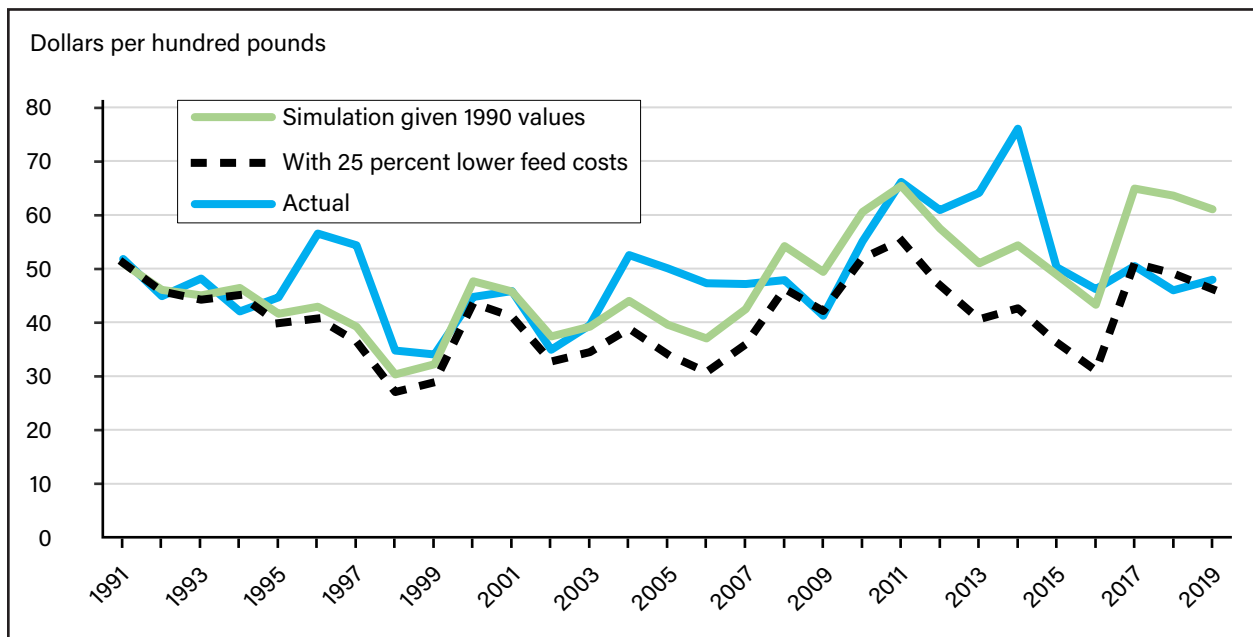
Hogs and Pork

Figure C3
Commercial pork production

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.
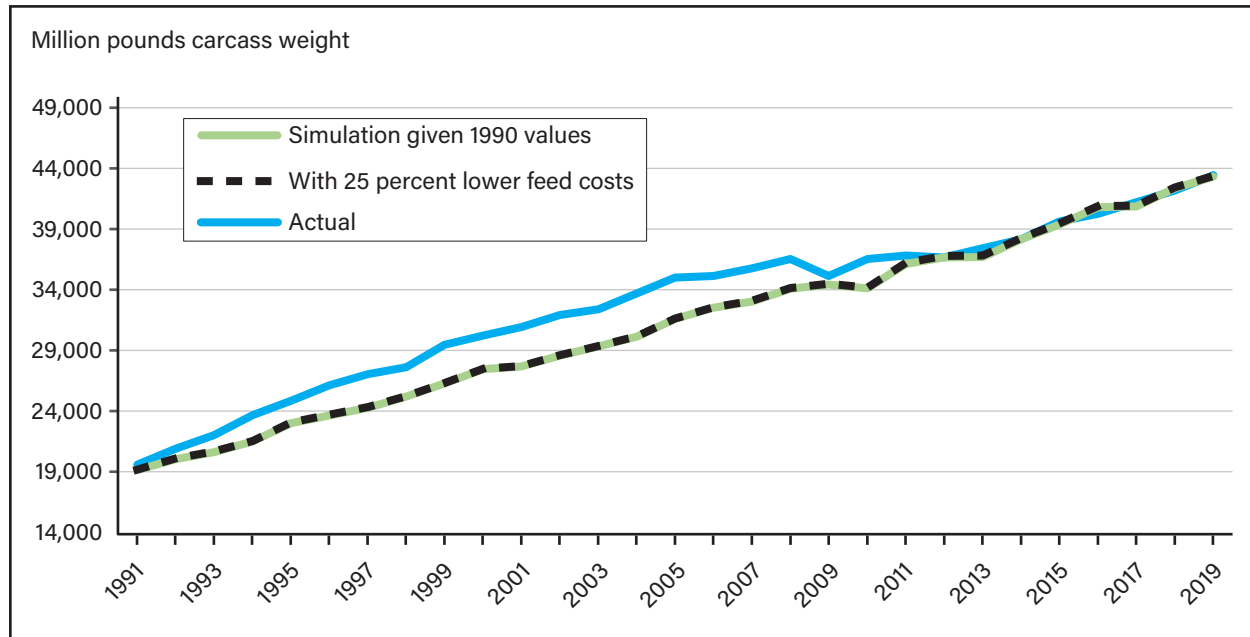
Figure C4
Barrow and gilt price

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Of the four species in the DBLM, hogs and pork are the most sensitive to feed costs. The 2019 lower-feed-costs total production is 9 percent higher than the multi-step forecast; hog prices are 26 percent lower. The sensitivity of pork supply to feed costs also makes the forecasts and simulations more volatile than those for the other three species.
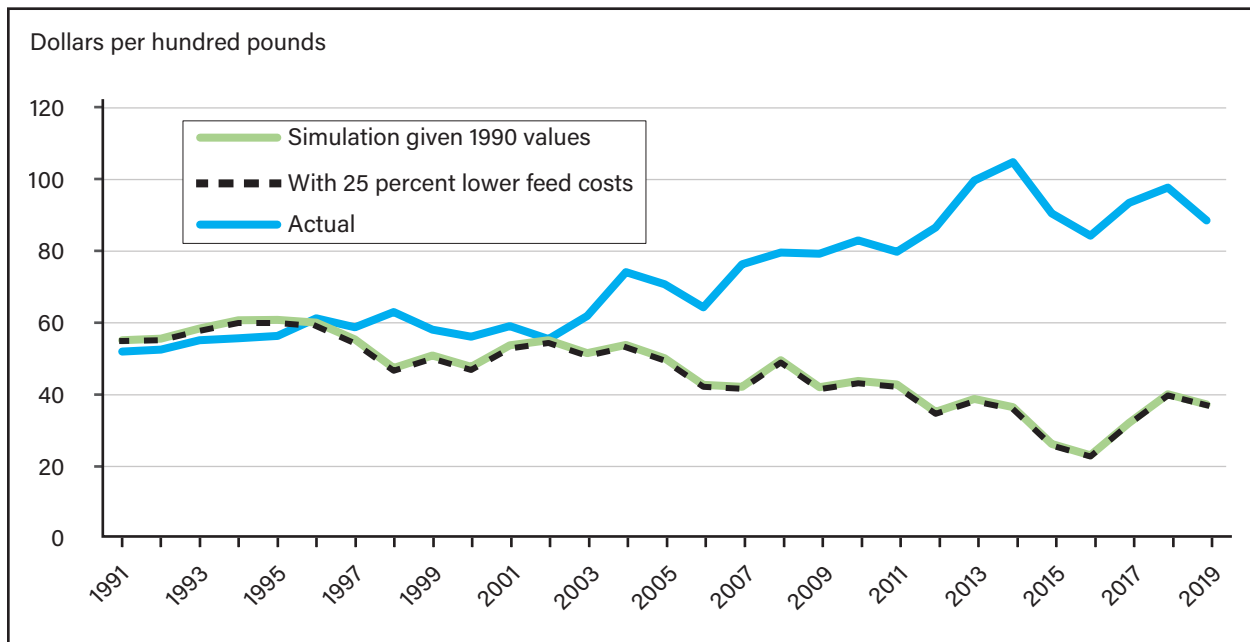
Broilers

Figure C5
Commercial broiler production

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

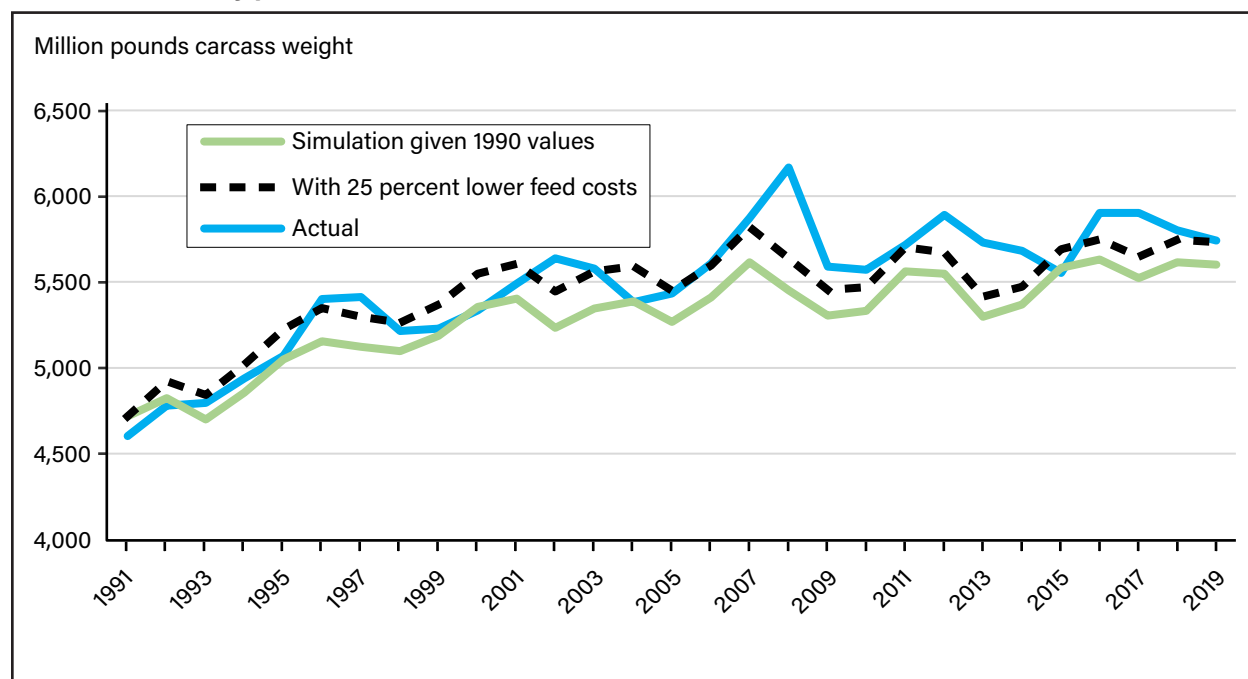Figure C6
Wholesale broiler price

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Broilers are the least-sensitive species to feed costs. The hatchery-flock equation (22) implies that the hatchery flock grows at approximately 1.2 percent per year. The hatchery flock drives the number of chickens hatched (equation 23). Feed costs are a factor in the number of chickens hatched. The multi-step total chicken supply forecast corresponds well with actual commercial production in the later part of the sample period. The wholesale price forecasts are consistently lower than the actual price starting in 2002, and the gap generally widens over time.
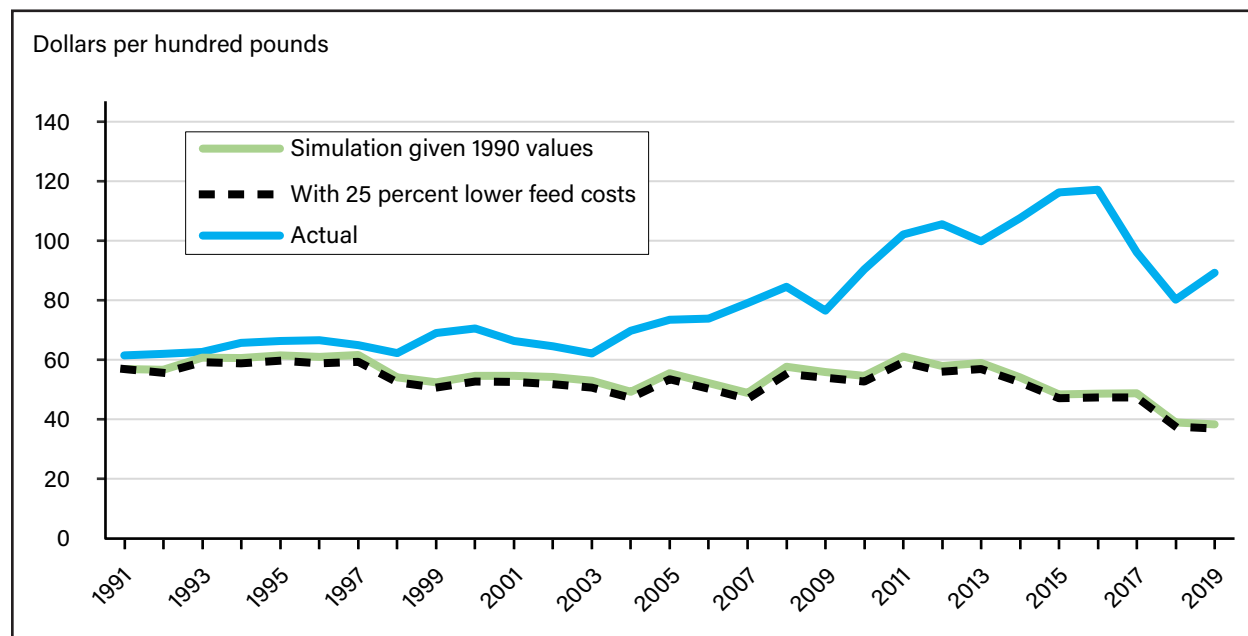
Turkeys

Figure C7
Commercial turkey production

Million pounds carcass weight

Source: USDA, Economic Research Service calculations using data from USDA, National Agricultural Statistics Service.

Figure C8
Wholesale turkey price

Dollars per hundred pounds

Source: USDA, Economic Research Service calculations using data from USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Turkey production in the DBLM starts with eggs (equation 26), which is a function of the lagged ratio between wholesale turkey prices and turkey feed costs. Simulated turkey production is relatively sensitive to feed costs, whereas wholesale turkey prices are not sensitive to feed costs. As is the case with broilers, the longer term wholesale price forecasts for turkey are much lower than the actual prices.